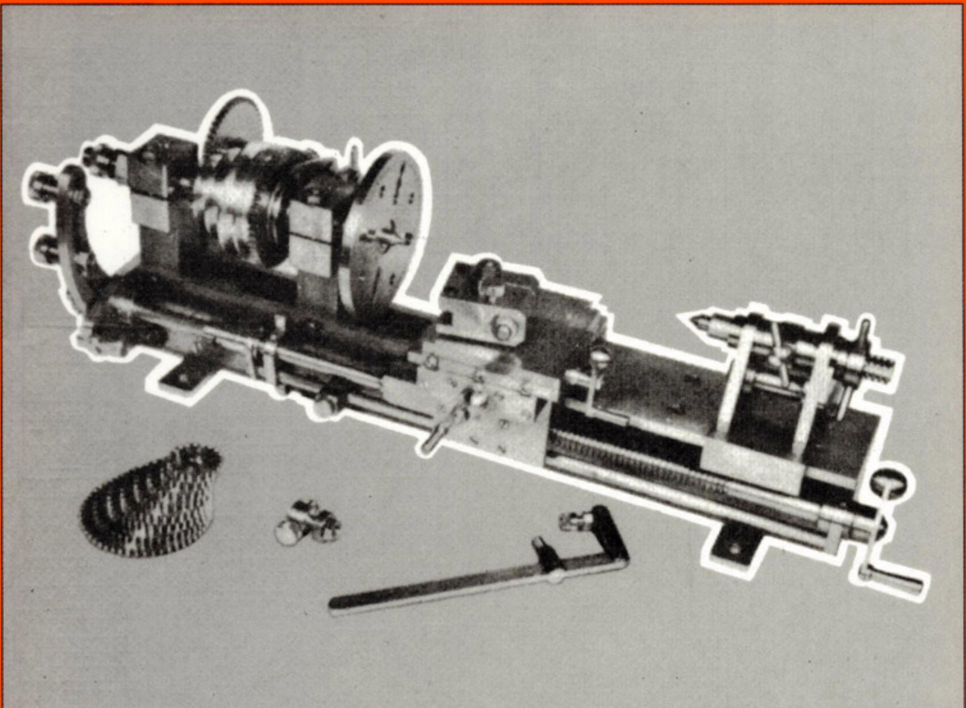
BUILDING A SMALL LATHE



L. C. Mason

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By

L. C. MASON

TEE

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WARNING

Since this book was first published, the Health and Safety at Work Act (1974) has been introduced in the UK. Similar legislation has been introduced in other countries. Such legislation has led to much greater emphasis on safety in workshops which has extended to many leisure activities. Neither the methods nor materials described in this publication have been tested to today's standard and consequently are not endorsed by the publishers. The reader, in pursuing construction and operation of any project, must exercise great care at all times and must accept that safety is their responsibility.

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Introduction

THE lathe has deservedly been called "The Prince of Machine Tools".

It can carry out—or be adapted to carry out—almost every machining operation that can be imagined, as well as a good many normally looked on as purely hand operations. Its ability to do this is not very often fully exploited in a commercial machine shop, where special purpose machines can each do a strictly limited number of jobs rather more effectively. Economics enters the picture here, and a heavily built machine that can remove more metal in a given time on some machining operation represents a good investment from the point of view of a greater output of work in that time.

These are not considerations that apply to the model engineer in the average home workshop. Time is generally of much less importance, and for reasons of cost if nothing else, the lathe is very often the only machine tool available. In these circumstances the lathe is frequently called upon to tackle a wide variety of machining jobs—some indeed, that could be better carried out on a different sort of machine.

Partly because of this, no doubt, it has been said that the majority of jobs that the amateur's lathe is called on to deal with are too big for it. That "majority" is perhaps a little sweeping, but certainly many are. If the size of the average amateur's lathe is taken as up to 4½ or 5 in. centre height, then it stands to reason that even more jobs must be too big for a really baby lathe. When we come to a lathe of the size presented here—1¾ in. centre height—then it might be thought that there can be few jobs that it can really cope with, and that all turning jobs are bordering on the "too big". This is very far from being the case, and a miniature lathe can put up an extremely good showing on a wide variety of jobs. A great deal of lathe work in general model engineering involves quite small components—small shafts, bushes, glands, nuts, special screws and innumerable bits that the baby lathe can tackle, perhaps much better than a far bigger tool.

Because a lathe is small in size and capacity, it does not have to be primitive. A fair proportion of commercially produced miniature lathes do not provide facilities for screwcutting for instance, yet a lot of screwcutting jobs are well within the capacity of a baby lathe to undertake. You can carry out screwcutting on the lathe described here, but with a somewhat restricted range of possible threads as compared with a full-size toolroom lathe. This is because of the size of the lathe itself; not because the lathe would not be able to cut extra fine or coarse threads, but because there is just not room to accommodate the size and number of change wheels required in a train to produce the gearing necessary for pitches of threads at the ends of the range. This restriction to the number of threads it is possible to cut might be said to have an advantage: it cuts down the outlay necessary on a much larger number of gears for a full set—and the ones eliminated are the largest ones at the expensive end of the series! Even so, all the conventional pitches of threads between 4 and 48 t.p.i. can be screwcut, which should cover most requirements. On most screwcutting lathes it is possible to set up a train of change wheels using the smallest and the largest in a combination to produce the finest possible thread. This is normally much too fine to be usable as a thread, but is quite useful as a "self-act" or power driven fine feed for the sake of a good regular finish on a parallel workpiece. This, unfortunately, is one facility which the builder will have to do without, as the finest feed that can be set up with the standard wheels as specified is 72 t.p.i., and this is too coarse for a finishing feed for normal turning.

Many commercially produced lathes, particularly in the amateur field, still

feature the clamp plate on the top slide for tool holding. The writer has never been very much in favour of this arrangement, as it does seem somewhat crude, and is a great time-waster in its need for assorted thicknesses of packing to go under the different tools.

In all the various lathes that the writer has owned during a lifetime of model engineering, the first job on acquiring a new one has always been to replace the tool clamp plate with a "proper" toolholder of the type fitted to this lathe. This presents any tool in any position called for, is really robust and rigid, and is instantly variable as to toolpoint height over a much wider range of adjustment than could normally be called for through tool changes or resharpenings. It has the advantage, too, that it is extremely handy for holding small items for milling from the chuck—again, with no separate packing pieces. As a last point, it is clamped in position on the topslide by one stud only, so that the clamp plate type can be fitted if preferred with no alteration to the topslide.

On this question of "preferred fittings", it has been kept in mind that if a number of people are going to build themselves lathes, they will not necessarily all want exactly the same thing. For this reason the design provides for the job to be built as a plain lathe only—i.e., no screwcutting—and in the same way the back gear feature can be completely omitted. Where such omissions make some difference to the procedure in building, the alternative procedures are mentioned as they arise.

With regard to the back gear, it should be pointed out that this is not intended to work in exactly the same way as a car gearbox. You use a car's lower gears for pulling away, shifting an extra heavy load, on a steepish gradient, or for any other purpose where extra power is required. True, there is more power available on the mandrel of the lathe when the back gear is engaged, but if it is used for this purpose there is some risk of straining the lathe. Its main purpose is the speed reduction produced, rather than the extra torque. A large heavily built lathe will remove metal from a job at speeds quite beyond the capacity of a much smaller, lighter machine. In this case, the purpose of the back gear on so small a lathe as this one is to enable the larger diameter job to be turned at all; to be turned at a speed within the capacity of the lathe to tackle.

So to move on to the actual building, there are no highly skilled or tricky operations involved. All the work is of a straightforward nature. It is generally claimed that you need a lathe to build a lathe, and this is true. Access to a lathe for many of the jobs is essential. The lathe shown was built entirely on a 3½ in. lathe, and all the turning has been successfully carried out on one smaller than that. When it comes to the actual assembly of finished components, all the fits and locations are adjustable for the sake of the accuracy of the finished job. The final accuracy is dependent on the amount of care you are prepared to take over it.

All the material comes from stock sections of mild steel bar and strip, and no castings at all are required. In many cases odd small items can be produced from scraps and "short ends" from the workshop scrapbox.

The detailed specification therefore is as follows:

Centre height: 1¾ in.
Distance between centres: 8 in.
Maximum swing on faceplate: 4 in. diameter.
Swing over saddle: 1⅞ in. diameter.
Overall sizes: Length 20 in., width (cross slide in) 7 in., height 5½ in.
Mandrel: ½ in. diameter, screwed ½ in., 16 t.p.i., bored $\frac{7}{32}$ in. through. No. 0 Morse.
Bearings: Split cast iron or bronze; adjustable.
Tailstock: Screw feed, bored $\frac{7}{32}$ in. through. No. 0 Morse.
Compound slide rest for ¼ in. squ. tools in adjustable toolholder.
Lead Screw: ½ in. diameter, 8 t.p.i.
Back Gear Ratio: 6¼:1.
Drive: ¼ in. round belt, 3 speeds.
Weight, with faceplate: 21¾ lbs.

CHAPTER ONE

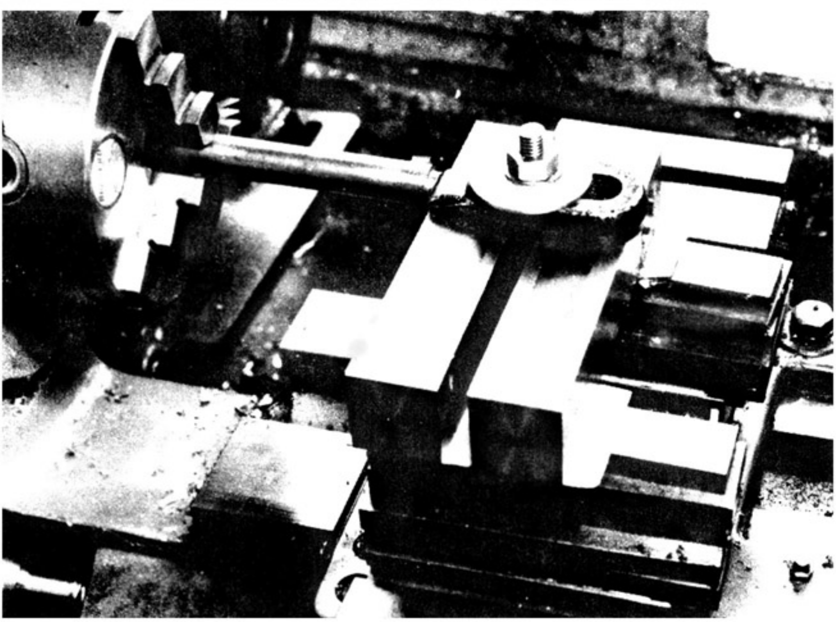
Headstock, Mandrel Bearings, Bed

IN commercially produced lathes of whatever size, the bed is almost invariably a massive casting, the basic accuracy of the lathe being assured by accurate machining of the casting. In a fabricated lathe bed of the sort described here, where instead of a casting the bed is built up from lengths of strip and bar, no machining of the bed is called for. Instead, the accuracy that would result from the machining is "built in" by careful adjustment of the pieces during assembly. This accuracy that is so much to be desired relates the features of the bed to the centre line of the lathe mandrel. As the mandrel is mounted in close fitting bearings in the headstock, it is logical to start construction with the headstock, lining up the bed to the headstock as assembly goes ahead stage by stage.

The headstock in the lathe shown consists of two vertical stout columns, the lower ends of which form part of the construction of the bed. Long side plates are bolted in front of and behind the columns, forming the "backbone" of the bed, while a true-edged plate is attached to the upper edges of the side plates to form the ways along which the saddle and tailstock can be moved. So a start can be made on the headstock columns, these being identical at this stage.

Each column is a $4\frac{1}{4}$ in. length of

Fig. 1. Boring the headstock columns for the mandrel bearing bushes.



1 x 1 in. square mild steel bar. Before you cut the pieces off the main stock, examine this closely and clean it up; if there are any dents or blemishes like bruised corners that cannot be avoided altogether, choose the two best opposite sides and make these the front and back sides of the columns. Give one side—say, the front—a streak of marking blue down its length, so that the columns can be kept in the same relationship to each other throughout as they were in the main bar. Remember, the bar may not be precisely the same dimension between one pair of sides as between the others! It will make for accuracy to have them both exactly the same thickness between the side plates. In marking the bar prior to cutting, mark also enough material for two 1 in. cubes marked on the same sides as the headstock columns themselves; these are required as spacers further down the bed towards the tail end, and they should also be just the same thickness as the columns.

The next step is to square the ends of the columns truly, bringing them both to length, and making sure that both are exactly the same length. This can be done either by very careful filing, fly-cutting or milling in the lathe, or by facing the ends in the four-jaw chuck, if the chuck available is big enough to accept them without too long an overhang. I managed the pair of columns shown in the 6 in. four-jaw of my ML7, using middle direct speed and light cuts. When you come to deal with the second end of each, adjust the column to run true if you are facing them in the chuck; if not, mark a centre punch dot truly in the middle of the squared end. You can drill fairly deeply here with a small centre drill, and later on this hole can

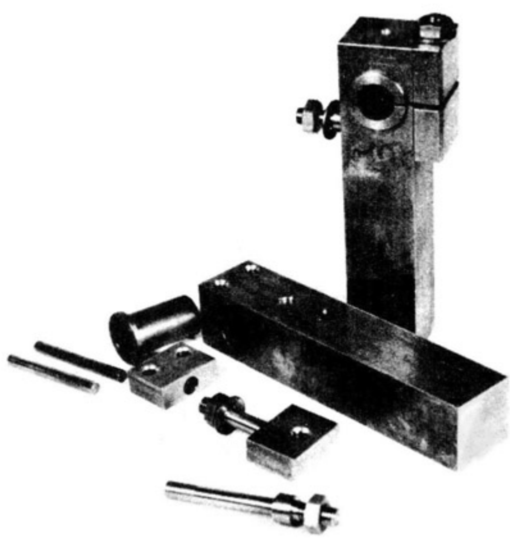


Fig. 2. Assembly of the bearing adjustment components to the headstock columns.

be extended downwards into the mandrel bush for lubrication.

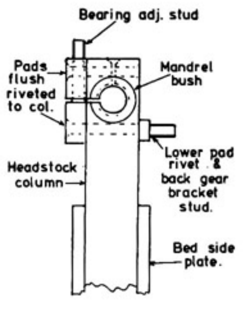
The next stage is boring the big hole in each to accept the mandrel bush. Mark the exact location of the hole on the L.H. side of the L.H. column—what will be the extreme L.H. end of the finished lathe—and arrange the columns on the saddle side by side, resting on substantial packing, so that the hole for a start can be drilled from the chuck. The photograph of this operation, fig. 1, shows what the set-up should look like. Make sure the packing brings the hole centre dot exactly to lathe centre height; you can check this against a small centre drill held in the three-jaw chuck. Make sure, too, that both bars are exactly square to the lathe axis and that their ends are level. Check for squareness across the lathe by nipping a rule between the L.H. bar and the faceplate, and then adjusting the R.H. bar to its neighbour by calipering across both bars till the feel shows them to be exactly parallel. Apply a square to the end of one bar so that the blade lays across the ends of both, ensuring that the hole will come exactly the same distance down the bar on both. Carry out this check on what will be the lower ends of the bars. Assembly of the columns to the side plates will be with the columns standing on a true surface, and it is desirable to have everything about the columns identical.

Don't forget the use of slips of paper under the job to prevent slipping, or as a minute adjustment to the thickness of the packing, and when you have everything correctly located, LOCK THE CROSS SLIDE!

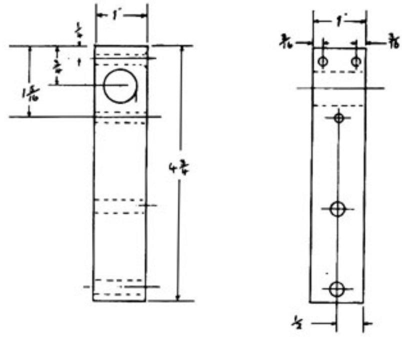
Start in to drill through the nearest bar with a centre drill, and then go right through with a smallish drill to provide clearance for the point of a much bigger drill. I used $\frac{3}{16}$ in. first, followed straight away by $\frac{7}{16}$ in. I have an oldish $\frac{9}{16}$ in. stub drill which I used to finish up with, for the sake of being able to get a $\frac{1}{2}$ in. boring bar through. For the actual boring out with the bar, you can use either a between-centres boring bar or one gripped in the chuck. If your biggest drill is not all that big, your best course would be to use a slim between-centres bar, as a thin bar held in the chuck would probably whip enough to produce a poor finish. I started with the $\frac{1}{2}$ in. bar in the chuck to see what the finish was like, and as this was quite satisfactory I used it throughout till the holes were out to size. Every now and then run the bar through without extending the cutter bit to deepen the cut, which will make for a good finish and a parallel hole. Aim for nicely parallel holes with a good internal finish, and as near as you can get them to $\frac{5}{8}$ in. diameter. When they are, the columns can come off the cross slide.

The mandrel bushes housed in these holes are split along their length, so that the bearings can be squeezed together fractionally to take up wear. In a headstock casting the appropriate lugs and bosses would be provided for the studs and clamp nuts by which such adjustment is carried out. In the plain columns here, these have to be added, and on each column they take the form of two pads riveted to the near side of the column at the top. The top pad has a hole drilled through it vertically, through which passes a stud forming part of the lower pad. A nut and washer on this stud at the top of the column can then minutely spring the top half of the bearing housing and bush, so adjusting the fit of the bearing bush on the mandrel. A sawcut through the side of the column and the bush at the bottom edge of the top pad enables this minute movement to take place.

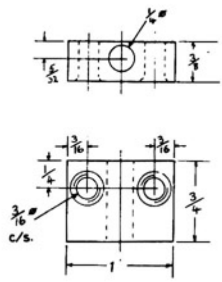
The mandrel bushes can be of any acceptable bearing material. The two best choices are probably bronze or cast iron. Cast iron is quite nice to machine, is much cheaper than bronze, and works very well on steel shafts. So iron was chosen in this case. Making the bushes can be the next job, as they have to be in place before the bearings can be finished right out with their adjustment arrangements. Perhaps the easiest way of machining up a pair of identical bushes is to start with a length of material long enough for both bushes, plus $\frac{1}{8}$ in. or so for sawing apart and facing the cut ends. Chuck the piece and face the outer end. Arrange enough material protruding from the chuck to allow of machining



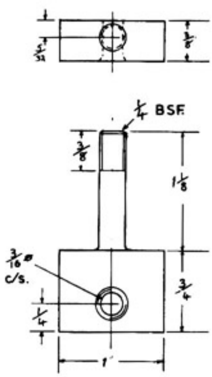
MANDREL BEARINGS ARR.

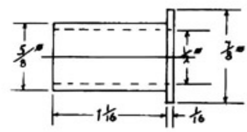


HEADSTOCK COLUMN 2 off

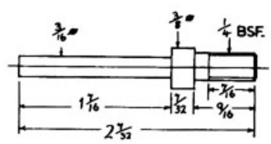


BEARING ADJUSTER PADS

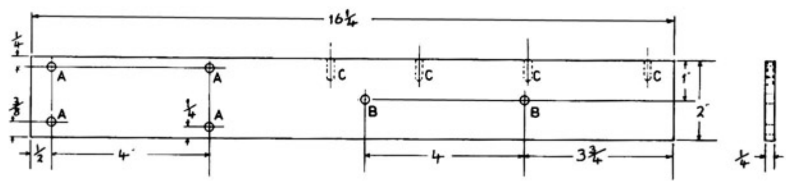




MANDREL BUSH 2 off



LOWER PAD RIVET 2 off



Holes: "A" $\frac{1}{4}$ ø; "B" $\frac{1}{4}$ BSF.; "C" 2 BA. ("B" $\frac{1}{4}$ ø in rear plate only)

BED SIDE PLATE. 2 off.

the whole of the outside of one bush. Turn down the one bush length to the diameter of the flange—if necessary. Then turn down the outside for $1\frac{1}{16}$ in. long to a very light press fit in the housing hole in the column. Don't forget to run round the end of the hole in the column with a fine half-round file to remove any burrs or sharp edges, or you can easily get a false fit with the bush when trying it for size.

It is best not to have the bush a heavy press fit in the column, else when the bush is split it may well be sprung in a trifle and be too tight on the parallel mandrel. Should you finish up with the bush a finger-push fit in the hole, that will probably be perfectly all right in service, as the slightest tightening of the adjuster will hold it. In addition, it could be set in position with a film of Loctite.

Starting with a centre drill, go halfway through the double-bush piece with increasingly larger drills, till the $\frac{7}{16}$ in. goes halfway in. Now reverse the piece in the chuck and turn the second half on the outside to fit the other bearing hole in the column, leaving sufficient large diameter material for both flanges in the middle of the piece. Drill as before, right through this time, stopping at $\frac{7}{16}$ in. diameter.

In the middle of the centre flange portion either part or saw the two bushes apart. Re-chuck one of them and face back the flange to finished thickness. The centre hole is now bored out with a normal boring tool, but the bore needs to be quite concentric with the outside of the bush. If the three-jaw chuck does not hold that diameter dead true, transfer the job to the four-jaw and get it running quite true before starting on the bore. Take it out to a nicely finished and parallel $\frac{1}{2}$ in. Treat both bushes the same.

Next comes the adjuster pads, and these are quite straightforward. Get them nicely squared up so that their edges fit well on the sides of the columns. Deal with the top pad first in each case, then each can be clamped in position on its column and the position for the rivet holes in the column spotted through the holes in the pad. These holes are $\frac{3}{16}$ in. diameter, and the rivets are in fact short lengths of $\frac{3}{16}$ in. mild steel rod. With the top pads finished and all ready for riveting on the columns, make the bottom portions next, before fixing the top pieces in position for keeps. You can then hold everything in position and check that the stud of the bottom half is quite free in the hole drilled for it in the top portion. If all looks in order, countersink the rivet holes lightly on the face of the top pad and the back of the column and rivet the top pad in position. After riveting, file the face nicely smooth, so that you really have to search for signs of the rivets.

The bushes should be set into place before attaching the bottom pads, then the lower edge of the top pad can be used as a saw guide for cutting a fine slit through the side of the column and the bush into the bore. Slip a narrow strip of tin or thin sheet metal into the bush when you saw the slit, to avoid scoring the bore should the saw plunge through a little unexpectedly on the last stroke. Note that the bush flanges are on the outer sides of the columns. Clean off any burrs resulting from cutting the slits.

The bottom pads are both riveted on the columns in the same way, except that only one rivet is used, and this is a bit "special". Instead of being a length of $\frac{3}{16}$ in. rod, it is turned up from a piece of $\frac{3}{8}$ in. diameter rod, as it has a small collar to bear against the back of the column, and an extension on this forming a short $\frac{1}{4}$ in. B.S.F. stud. The purpose of this is to provide a stud for attaching one of the brackets carrying the back gear shaft. It is a simple turning job to the drawing, and in riveting it in position, the screwed portion should be prodded into a $\frac{1}{4}$ or $\frac{9}{32}$ in. hole drilled in a stout bar held in the vice, so that the riveting pressures are taken on the collar and not on the threaded end of the stud. The back of the hole in the column is not countersunk under the collar, of course. Note that if you are proposing to build the job as a plain lathe only, with no back gear, then the lower pad can be riveted in place with a plain rod rivet, just like the top.

With the bearing bushes duly split, the bottom adjuster pads can be fixed in place. These are riveted on like the top pieces, but using the "rivet-cum-stud" for

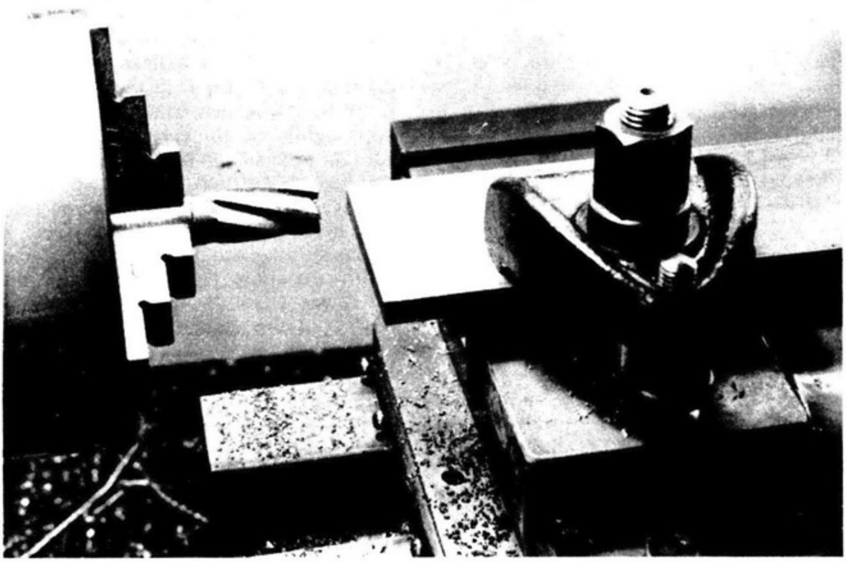


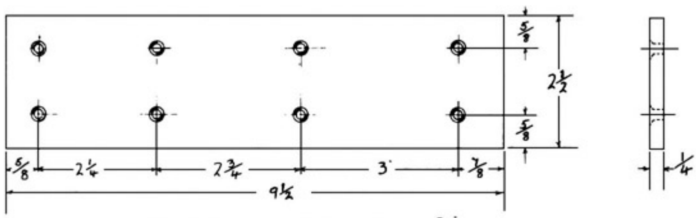
Fig. 3. One way of ensuring square ends on the bed plates; end milling in the lathe.

each. When all is finally in place, you will probably find that with a piece of true $\frac{1}{2}$ in. diameter bar through the bush, something like half a turn on the top adjuster nut is required before the bar is beginning to be gripped tightly in the bush. This is as it should be. As a last operation on the columns before assembling them to the bed, drill down in the top centre hole through into the bush for the oil hole. A drill about No. 45 size is suitable here.

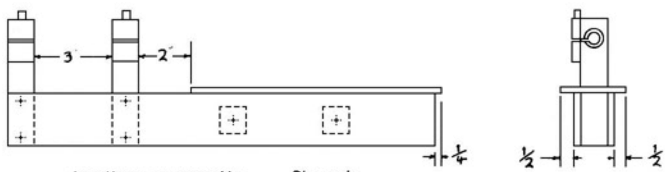
So moving on to the next part of the bed, the side plates can be taken in hand. These should be checked over like the column pieces for dents, scars and general blemishes and anything of this sort corrected before starting in to shape them up. Cut each to length so that they will square up to $16\frac{1}{4}$ in. long. The ends need to be quite true and square, and these can be dealt with by filing, or as I did, by end-milling them in the lathe. The photograph, fig. 3, shows the set-up for this, the plates being squared to the faceplate. Get both exactly the same length. The drawing shows the pattern of holes drilled in each for the assembly bolts and the plates are lined up to the mandrel before completing the drillings for the bolts.

The top plate could be taken in hand here too, getting this nicely squared up and finished to $2\frac{1}{2}$ in. wide x $9\frac{1}{2}$ in. long. Check that it is nicely flat, with straight and true edges, as these edges guide the saddle and tailstock.

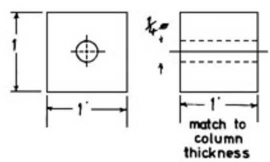
The four holes for the bolts through the columns are drilled in the front plate only for a start, then on getting everything lined up satisfactorily, they are used to spot through on to the columns so that the holes come in just the right place. The two holes further down the bed receive similar bolts which clamp the spacers in position between the two side plates. These spacers not only ensure that the side plates are pulled quite parallel throughout their length, but stiffen up the bed as a whole. The holes for these



TOP PLATE B.M.S. All holes 3/16" c/s.



Locations on assembly. Diag. only.



SPACER 2 off

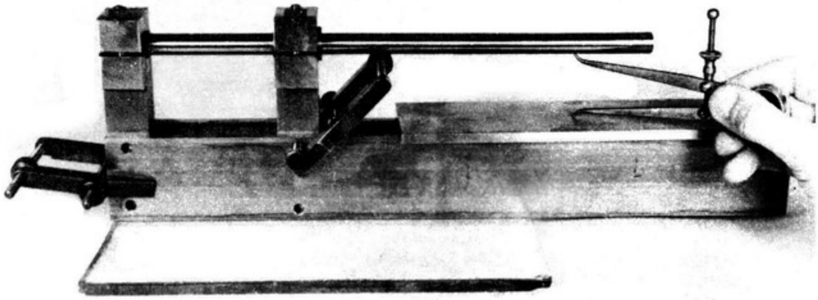


Fig. 4. Aligning the bed plates horizontally to the centre line of the mandre

two bolts are drilled in the BACK plate only in this case, as the bolts are tapped into the front plate instead of nuts being used on the outside. This is because they come in line with and behind the lead screw, and there is not enough room for nuts between the lead screw and the front side plate. By carrying out these drillings from the back, the spacer can be used in place between the plates to act as a drill guide for starting the drill into the front plate for the tapping size hole.

The drawings specify $\frac{1}{4}$ in. diameter holes as for $\frac{1}{4}$ in. B.S.F. bolts. However, if you obtain the bolts before drilling any holes, you will probably find that the diameter of the bolts over the threads is quite distinctly less than $\frac{1}{4}$ in. There are two possible alternatives here which will provide a better fit for the bolts than a plain $\frac{1}{4}$ in. hole; you can either use short lengths of $\frac{1}{4}$ in. rod threaded for a nut each end, or select a drill slightly smaller than $\frac{1}{4}$ in. which is a better fit for the bolts. I took the latter course, as I found that letter "D" drill produced a hole that was a really snug fit for the bolts, with no play at all.

So having decided on the course of action, drill the plates as shown. The trial assembly needs to be carried out on a really flat surface. A large surface plate is the ideal, but lacking access to such a thing, the next best is a fair sized piece of plate glass—the thicker the better. It will be seen from the photographs that this is what I used, and this worked very well. The piece shown is, in fact, the workshop "surface plate"!

With the front plate drilled, stand it on the surface plate, position the R.H. column behind it in the correct position and clamp the two together as they will come when assembled. Spot through the plate on to the side of the column, separate the two and drill through the column dead squarely. De-burr the hole both sides of the column. In the fit-up to come, a bolt is prodded through the front plate and the column, and on any movement of the column to adjust the mandrel line, the column pivots on this one bolt.

Now stand the columns up in place, position the side plates either side of them, and hold the whole lot together with a couple of large toolmakers' clamps lightly nipped up. Get the columns truly perpendicular—as checked with a square on the top edges of the plates—and exactly 3 in. apart. They should automatically be square, of course, because the ends on which they are standing should be square to all the sides. Get the L.H. ends of the plates exactly level with the outer surface of the L.H. column,

and check with the square across the R.H. (tail) ends of the plates that these also come square and dead level. When they look to be positioned correctly, nip the clamps up a bit tighter.

The line of the mandrel for test and assembly purposes is taken from a standard 13 in. length of ½ in. diameter silver steel slid into the bearings. So pop this into place now, and if necessary adjust one or other of the columns till it can turn freely in the bearings with the clamps tight. When this is correct, nip down the adjuster nuts till the bar is just too stiff to be turned by hand. If you have had to move anything to accommodate the test bar, re-check all round for squareness and level ends, checking also the 3 in. distance between the columns.

Now add the prepared top plate, laying this in place so that its L.H. end comes 2 in. from the nearest column. In this position, the R.H. end should overhang the ends of the side plates by ¼ in. Check that it lays nicely flat along the whole of its length on the top edges of the side plates, with no rock across the corners. The tiniest amount of rock can be adjusted by fractional movement of one or other of the side plates, but any sizeable movement necessary indicates that something is not flat, or a plate is warped, and this should be corrected before going any further.

With everything in order so far, the last check is to see that the test bar is parallel to the top plate. The photograph shows this being carried out, and it is a

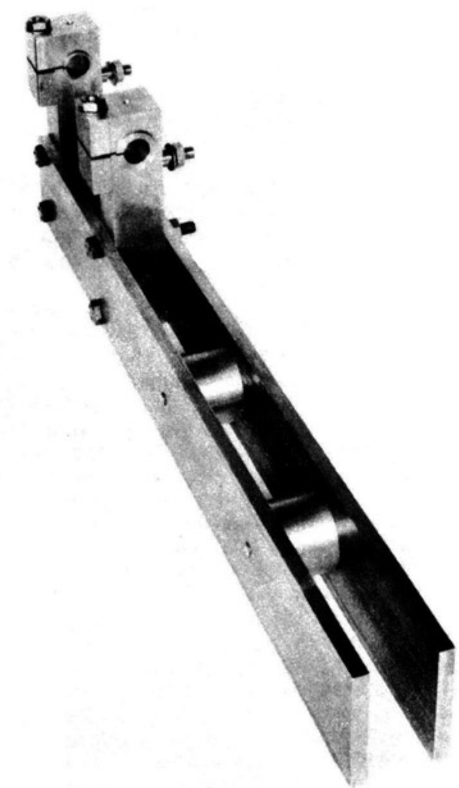


Fig. 5. Stiffening spacers assembled between the bed plates.

matter of gentle feeling with the inside calipers. To get this right if adjustment is called for, ease off the clamp pressure somewhat and gently tap the L.H. column a fraction up or down, so that the R.H. one pivots on its one bolt. Use a piece of wood for the tapping business, so as not to bruise and mark the columns. After any adjustment of this sort re-check all round for level ends and general squareness, and correct if required. When satisfied that all is as correct as you can get it, tighten the clamps up hard, add any others where you think they might help to make sure of things, and start in on drilling the bolt holes. Remove the pivot bolt from the R.H. column for a start and complete the drilling in that hole through the back plate. De-burr the hole, fit the bolt and nut up tight. Drill the lower one in the same column next, going through column and back plate. De-burr and bolt up as before, when the clamps looking after that column can be removed. Treat the L.H. column the same, fitting both bolts and nutting up before removing any more clamps. A final check all round should show the bolted-up assembly so far to be as square and accurate as when merely clamped together.

When the headstock columns are bolted in position between the side plates the spacers further down the bed can be dealt with. In talking of checking and cutting up the square bar for the columns, mention was made of providing enough square material for the spacers as well. It will, no doubt, be noticed that the spacers shown in the photograph are round. This is because a 10 in. length only of the 1 in. square bar was available, which was only just enough for the columns, so the spacers were turned from a short end of $1\frac{1}{4}$ in. diameter round steel. Builders can please themselves which course they adopt—depending perhaps on what may be available—but if round spacers are used, they should not be less than say, 1 in. diameter. In making round ones, face one end of the piece, saw or part off full long, then face back the cylinder so that it is a "finger-push" fit between the plates. Check the fit close up to the column. Drill through for the bolt in the lathe when the second end is faced, de-burring both ends of the hole. Square spacers can be faced off to any length over 1 in., drilling the bolt hole squarely through the marked face so that the faces nipped between the plates will match those of the columns.

To finish off the drillings for the bolts, slip a spacer between the plates to line up with the bolt hole in the back plate nearest the columns, start the clearance size drill through the already drilled holes in the back plate and spacer, and run it about $\frac{1}{16}$ in. into the inside of the front plate. Withdraw drill and spacer and finish the hole right through the front plate with No. 5 drill from the back. Tap $\frac{1}{4}$ in. B.S.F., making sure that the tap goes through absolutely squarely. Re-fit the spacer and bolt it in position with a bolt shortened to $1\frac{1}{2}$ in. long under the head. This will bring the end flush with the surface of the front plate. Treat the tail end spacer the same. A re-check all round—including that with the test bar—should show everything still in order.

Next comes fitting and adjusting the top plate—or perhaps it should be the other way round, adjusting and final fitting, as this is located from the test bar in much the same way as were the columns.

Mark out the position for one holding screw—the one nearest the columns going into the back side plate. The screws used are 2 B.A. x $\frac{3}{8}$ in. countersunk, and the same thing may be found with these as with the bolts holding the headstock columns. The clearing size drill for 2 B.A. is generally given as $\frac{3}{16}$ in., but if you check a screw or two for diameter you will most likely find that you can use a smaller size clearance hole than $\frac{3}{16}$ in. for a snug fit. My particular batch of screws were a nice fit in a No. 14 hole, which is .182 in.—a full 5 thousandths less than $\frac{3}{16}$ in. So if I refer to the $\frac{3}{16}$ in. holes for the screws, you can take it I don't really mean that! However, whether you adopt $\frac{3}{16}$ in. or something smaller, drill the one hole in the top plate 2 B.A. TAPPING size—No. 24 or so. Locate the top plate in position on the bed, 2 in. from the column, and overhanging the

tail end of the bed by $\frac{1}{4}$ in. Mark through the hole for the screw hole position on the top edge of the side plate and drill the tapping hole down a full $\frac{1}{2}$ in. deep into the top edge of the plate, taking care to get it dead in the middle of the side plate thickness; there is not too much room for wandering from the proper position with a $\frac{3}{16}$ in. diameter screw in $\frac{1}{4}$ in. thick material!

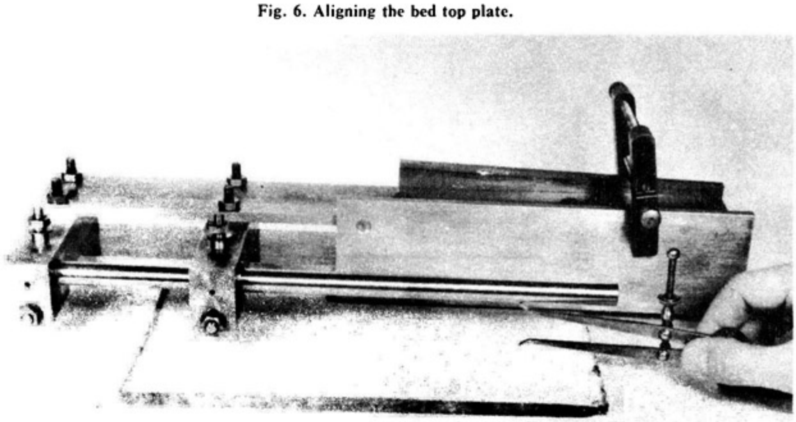
Incidentally, the L.H. end of the top plate stops short of the headstock columns for two reasons: by doing so it provides a space for the turnings and swarf to drop away through the bed. and it also forms something of a "gap" in the bed. This is small, it is true, but nevertheless it does add another useful $\frac{1}{2}$ in. to the maximum diameter that can be swung on the faceplate.

Tap the hole 2 B.A. and open up the hole in the top plate to $\frac{3}{16}$ in.—or whatever modified size you have decided to adopt. Countersink the clearance hole on the top of the plate deeply enough to let the screw head come fractionally below the top surface and screw the plate into position on the bed with just the one screw in the back corner.

Lay the whole assembly on the surface plate on its nearside and pop a stub end of $\frac{1}{2}$ in. diameter rod under the lower side plate. This will bring the surface of the top plate nearly enough vertical and square to the surface plate. Slip an odd piece of the $\frac{1}{4}$ in. plate over what will be the bottom edges of the side plates—now at the back—and nip it in place with a large toolmakers' clamp over it and the top plate. The photograph, fig. 6, shows the arrangement. Replace the $\frac{1}{2}$ in. test bar through the mandrel bearings and with the clamp slack enough for things to be moved, start in to adjust the test bar level with the surface plate, the bed swinging on the one screw in the top plate. This is another operation relying on caliper feel, moving the tail end of the bed fractionally up or down till the feel of the calipers between the underside of the bar and the surface plate is just the same next the column as at the tail end. This is quite a sensitive adjustment, and as you get nearer the exact position the movement necessary to alter things is minute. When you have got it right, pinch up the clamp and the top screw tight. Re-check that tightening these has not moved anything.

Having done all that—this is just a preliminary work-out! Mark a clear line with the scriber on the underside of the top plate right along the angles between the top plate and each side plate. Do the same inside, between the side plates as far as you can reach, getting a mark if

Fig. 6. Aligning the bed top plate.



at all possible roughly where the rest of the screw holes will come. With these lines marked, remove clamp, screw and top plate. The scribed lines under the top plate will now give you a clear guide as to where the rest of the holding down screws should come so that they can be positioned exactly in the middle of the thickness of the side plates. So the next step is obviously to mark these out and drill them—tapping size for a start. Very lightly countersink each on the underside, so as to be sure that the plate will lay down flat on the side plate edges. Replace the top plate on the bed as before with the one screw, the underneath packing piece and the clamp, and start in to line it all up again on the surface plate. This time it really must be right, as this is the locating for the final fixing. When you are sure you have got it as good as you ever will, tighten everything, re-check, and spot through all the holes with the tapping size drill into the side plate edges, running the drill in about $\frac{1}{8}$ in. or so.

Strip off everything again, when you should see that the start of the tapping holes in the side plates are correctly located. Deepen each of these with the tapping drill to a full $\frac{1}{2}$ in. deep and tap them all 2 B.A. exactly squarely to the plate top edges. Open up the tapping size holes in the top plate to the clearing size and countersink on the top so that they all match the first corner hole. Re-check the holes on the underside for burrs, and clean up as required.

On assembling the top plate to the bed with all the screws finally, everything should take up its final position snugly, and a re-check for alignment should prove everything true.

Perhaps it may be thought that the bed assembly procedure has been described in unnecessary detail, but the importance of carrying this out methodically and painstakingly is very real if the finished lathe is to be capable of accurate work. For this reason it is well worth spending a little time at this stage in getting everything really "spot on"—it will pay dividends in the future.

This completing the building of the bed, you could if preferred finish it right off at this stage by adding the feet. However, it is convenient to have the nearside of the bed clear of anything like feet when fitting the lead screw and sundry other pieces that go with it, so if you do fit the feet now you will probably find it helps considerably to remove them when you come to work on the front of the bed. Furthermore, there are other bits and pieces attached at both ends of the bed near the feet, and I preferred to get these components sorted out and fitted first, then the position of the attachment points for the feet could be checked that they come well clear of more important pieces nearby.

CHAPTER TWO

Tailstock

THE next item to take in hand could well be the tailstock. Getting this lined up uses again the silver steel test bar that was first used in building the bed and headstock, as the tailstock is also related to alignment of the bed and bearings. It will be needed again for similar operations to come, so do not discard it altogether yet.

In construction, the tailstock could be looked on as two units; the base, and the body with its triangular plates permanently fixed to the base.

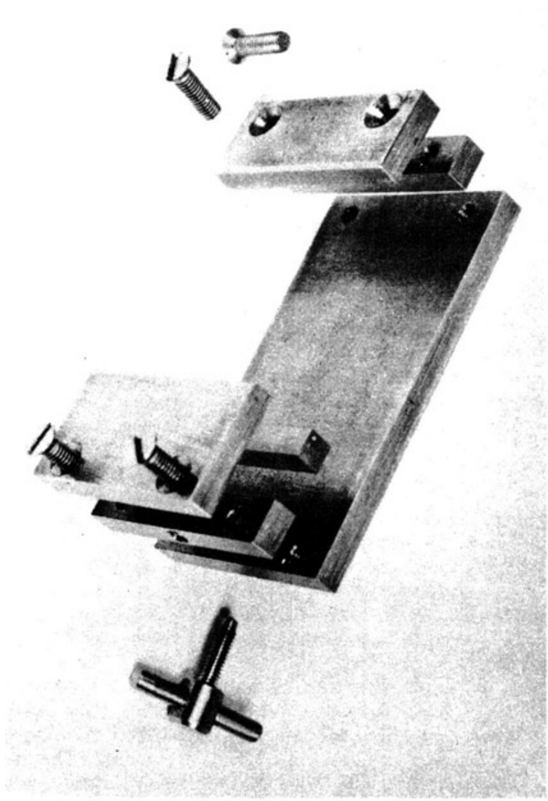
The base is the piece to start with, as this needs to be finished to be able to line up the body and so finish that. Work on the base is all quite straightforward, consisting of building up the ways which embrace the edges of the bed top plate. At both front and back they are built up from a sandwich of two strips of the $\frac{1}{4}$ in. plate, the pack held together by two 2 B.A. countersunk screws inserted from underneath. At the back, what amounts to a thick gib strip can be nipped in to grip the bed edgewise, thus locking the tailstock on the bed in any position required.

There is little that need be detailed in the construction of the base, the main point to watch being to get the various strips all parallel and nicely square in all directions, with good smooth surfaces on the rubbing edges. When each pair is finished ready for assembly to the baseplate, clamp them all together in a pack, lining up the ends and edges. Drill right through the three 2 B.A. tapping size—No. 24 or so—release the clamp and open up the tapping size holes in the two narrow strips to clearing size. Countersink the hole on the outside of the widest strip to accept the 2 B.A. screw flush. Tap the holes in the baseplate. Screw the pack together and try the fit on the bed. If it is too tight, either file down that part of the under surface of the bottom strip a fraction where it contacts the bed, or insert a shim of one or more thicknesses of baking foil next the middle strip. Should it be too slack, file down the thickness of the middle strip a fraction. In any filing fit adjustment of this sort take particular care to keep the filed surface really flat. Treat the assembly at each end of the baseplate the same, till the base will slide snugly the full length of the bed. The $\frac{1}{4}$ in. square locking strip will probably need a little treatment top and bottom till it is quite free to move between baseplate and under strip. Completing the locking strip details as shown finishes the tailstock base. The little finger screw for locking it to the bed is a simple turning job from $\frac{3}{8}$ in. diameter mild steel rod, and the handle is merely a short length of $\frac{3}{16}$ in. diameter rod pressed into a cross hole. Drill the hole No. 13 (.185 in. diameter) and if the drill makes a hole a thousandth or two over nominal size, this will probably be about right. If it drills dead to size, you may have to reduce the $\frac{3}{16}$ in. rod a trifle to get it in. Just chuck the rod and give it a few strokes with a smooth fine file while running in the lathe.

The next thing to take in hand is the body, and there is a bit more work in this than in the base. Start with the two plates. Cut them full long (or high) for a start and get one end of each nicely squared up. You need only treat one end of each, as the other end is rounded off to form a neat top. However, leave them square for the time being till all the work is completed on them, as they will then be easier to hold in the four-jaw chuck.

Each plate has two holes in it; a big $\frac{11}{16}$ in. diameter one at the top in which is mounted the barrel housing, and a smaller one below which is used for the main bolt which holds the spacer in place. All the marking out can be done on one plate only—preferably the R.H. one at the tail end, which we could call the back plate. Treating the squared end of the plate as the bottom, mark in a vertical centre line on which the two

Fig. 7. 'Exploded' view of the tailstock base components.



holes will come. Measuring up from the true bottom edge, mark in and punch dot the centres of these two holes, locating them so that they are the correct distance apart, but both are about $\frac{1}{32}$ in. too high up the plate. This is so that when the tailstock body comes to be assembled on the base, the height of the tailstock barrel can be accurately adjusted to come dead level with the mandrel centre line.

With the one plate marked out, clamp the two together—marked plate on top—and with the bottom edges and sides exactly level with each other. Drill through both at the bottom hole position with No. 5 drill ($\frac{1}{4}$ in. B.S.F. tapping size). Separate the two and open up the hole in the front plate with the drill used for the $\frac{1}{4}$ in. bolt clearance holes in the bed plates. Tap the hole in the back plate squarely $\frac{1}{4}$ in. B.S.F. Find up one of the $\frac{1}{4}$ in. bolts as used for the bed and cut this down to about $\frac{5}{8}$ in. long under the head; putting the two plates together again as they were before, get them exactly level again and bolt them together tightly with the shortened bolt.

Mount the pair in the four-jaw chuck, marked plate outwards, and get the top hole centre dot running true. Check with a try square from the cross slide that the plates are really squarely mounted in the chuck so that the holes will come square and true. Drill through at the centre dot and open up with a boring tool to a

smoothly finished $\frac{11}{16}$ in. diameter. When the hole is out to size, counterbore the outer surface to $\frac{13}{16}$ in. diameter, $\frac{1}{16}$ in. deep.

That finishes the body plates to about as far as we can go with them at this stage, and the next piece is the barrel housing that goes in the two holes just bored. This is turned up from a $1^{15}/_{16}$ in. length of 1 in. diameter steel rod. Face both ends to bring it to length, and on one end mark in a centre dot $\frac{3}{32}$ in. off centre, using the machining marks on the end to pinpoint the centre. Chuck the piece in the four-jaw and get the off-centre dot running true. I chose to do the bore for the tailstock barrel first, on the grounds that this needs to be nicely finished and to correct size, and if I slipped up anywhere I was not wasting time in scrapping some other work! So start in to drill the end at the dot with a largish centre drill and go right through steadily with a drill about $\frac{9}{32}$ in. or so. The bore must finish to a smooth $\frac{1}{2}$ in., so follow up with something like the $\frac{7}{16}$ in. drill, leaving $\frac{1}{32}$ in. to come out for finishing. A boring tool slim enough to reach right through the bore will have a very long overhang for its size, so in case the inevitable spring leaves the bore with a poor finish or not quite parallel, leave a few thousandths still to come out for the final finishing and finish up to size with a $\frac{1}{2}$ in. reamer. The finished bore should be a smooth and shakeless fit on the $\frac{1}{2}$ in. silver steel test bar.

With the bore finished, leave the piece undisturbed in the chuck, as there is some machining on the outside which needs to be concentric with the bore. Reference to the drawing will show that there are several diameters involved on the outside. For a start, there is a maximum diameter belt left in the middle, and it is in this that the barrel lock screw is tapped. The object of locating the bore eccentric to this diameter is to provide a greater depth of thread for this screw than would be available if the whole thing were concentric.

Both ends of the piece are turned down to $\frac{11}{16}$ in. diameter to fit the holes in the plates. The end fitting the front plate is turned down for a length of $\frac{1}{2}$ in., forming the nose of the housing, and is a stiff push fit in the plate. The other—the back end—is $\frac{11}{16}$ in. diameter for a length of only $\frac{3}{16}$ in. and is a press fit in the back plate, the end of the housing coming flush with the bottom of the counterbore in the plate. Incidentally, the counterbore receives the end of the barrel feed wheel, which is held in place by a keep plate screwed to the back of the end plate. The reduced part of the housing fitted in the plate ends at a shoulder pressed into close contact with the inner surface of the plate when the housing is pressed right home. This larger diameter next the plate has a small flat filed on it at the bottom, and this fits closely against a similar flat filed on the flange of the spacer mounted below. This provides a positive lock to the housing preventing any possibility of it turning in the plates, such as might conceivably occur under the stress of drilling from the tailstock, for instance.

When the bore is finished, without disturbing the piece in the chuck, turn down the outer $\frac{3}{16}$ in. to $\frac{11}{16}$ in. diameter, a light press fit in the counterbored end plate. Remember to file a minute chamfer on the leading edge of the hole so as not to get a false fit on trying the housing end for size. In arriving at the final size, arrange a very slight "lead" on the end, so that the housing can be jammed into the beginning of the hole by hand; this will come in handy when lining up the tailstock to the test bar before it is all finally assembled and squeezed together.

With that portion down to the right diameter, run the next $\frac{7}{16}$ in. down to $\frac{13}{16}$ in. diameter, which should see the tool just cutting all round. Having this round portion now concentric with the bore enables the rest of the turning to be done rather more conveniently in the three-jaw—providing your chuck holds quite true at that diameter. So change over chucks and re-chuck the piece by the last turned diameter, and check for true running with reference to the bore. If it is not dead true, pack one or more of the jaws with slips of paper, or else switch back to the four-jaw to get it right.

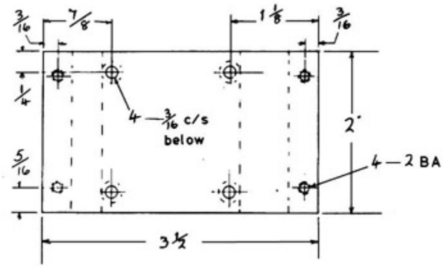
The first diameter to be turned on this end is the $\frac{1}{2}$ in. long nose, and this wants to be a stiff push fit in the $\frac{11}{16}$ in. hole in the front plate. Having got that sized correctly, the next move is to repeat the turning of the $\frac{13}{16}$ in. diameter portion on this end, which should leave you the central eccentric belt the full original diameter and $\frac{3}{8}$ in. wide. Neither the width of this nor the $\frac{13}{16}$ in. diameters are at all precise, and a nice finish for the sake of appearance is as important as exact size. All that remains to be done to the housing now is the filing of the locking flat, and this could be left till the spacer is made, when the two could be dealt with together to ensure snugly matching flats.

The big diameter centre portion in which the barrel lock screw runs is not left as a plain eccentric, but presents a much neater appearance if shaped into something like a cam, with the nose tapped for the screw. So shaping this might well be the next step. I removed most of the metal to come off by end-milling, as it is very easy to set up the piece for this by mounting it vertically on a suitable piece of packing on the cross slide with a single bolt through the bore. Provide a soft washer each end so as not to bruise the piece. First set it up so that the "nose" of the cam comes next the chuck, and mill a small flat about $\frac{5}{16}$ in. wide in which to drill for the tapped hole. The piece can then be turned on its holding bolt so as to be able to mill off the tangential straight sides of the cam. The slight corner where these end at the round body can be quickly blended into the body shape by filing. When the finished shape is satisfactory, drilling and tapping the lock screw hole 2 B.A. in the centre of the flat finishes the job.

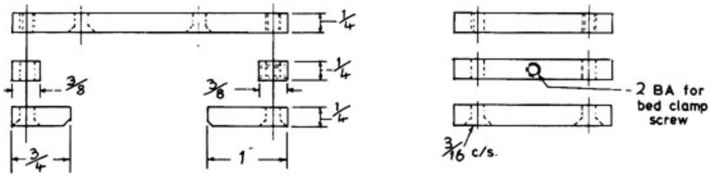
Another cylindrical piece with an eccentric bore is the flanged spacer fitting between the plates below the barrel housing. This needs to be $1\frac{1}{4}$ in. long; if you turn it from a piece of 1 in. diameter rod about $2\frac{1}{8}$ in. long, you have a convenient $\frac{3}{4}$ in. extra length by which to chuck the piece, and this extra bit can be used for the barrel feed wheel. So face up both ends of the piece and mark off the centre for drilling for the bolt $\frac{1}{16}$ in. off the true centre. Set it up in the four-jaw with the eccentric centre dot running true and drill in no more than $1\frac{5}{16}$ in. with the bolt clearing drill. If you are not going to use the spare chucking piece for the feed wheel, then you could go right through if you prefer. Turn in the $\frac{1}{2}$ in. diameter "waist" first, forming the $\frac{1}{8}$ in. thick eccentric flange at the outer end. At the other end next the chuck, turn the piece concentric for the other flange—about $\frac{7}{32}$ in. wide—and by the time the tool is cutting all round you should be about the correct finished size, $\frac{7}{8}$ in. diameter. Part it off to finish $1\frac{1}{4}$ in. long overall. If you part (or saw) it off a shade long so as to be able to finish face that end to correct length, it is not too easy to hold in the chuck by the one eccentric flange. However, it can be done; one way is to grip the bolt clearing drill in the tailstock chuck, impale the spacer on it, and then feed it between the opened jaws of the chuck by the tailstock feed, when gently closing the chuck and withdrawing the drill should leave it truly gripped.

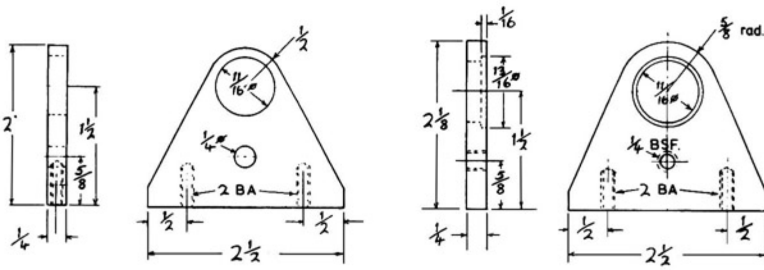
With the spacer finished, the locking flats on it and the housing could be dealt with. You should find that with the spacer positioned so that the furthest reach of the eccentric is upwards towards the housing, the flange edge will just begin to overlap the $\frac{11}{16}$ in. hole in the plate. A flat about $\frac{1}{8}$ in. or so long on both the spacer flange edge and the $\frac{13}{16}$ in. diameter of the housing should just let the two pieces settle closely together on the back plate. File the flat on the housing first, not quite down to the $\frac{11}{16}$ in. diameter, and then that on the spacer flange, taking both gradually deeper till they both fit snugly on the plate—the spacer temporarily on its bolt, of course. In positioning the flat on the housing, it is worth while arranging it so that the hole for the lock screw is inclined about 20 degrees or so upwards; this makes sure that the arms of the lock screw easily miss the sloping edges of the plates, and provides a little more finger room to operate it.

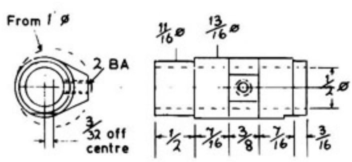
All the parts so far made should now go together firmly enough for the lining-



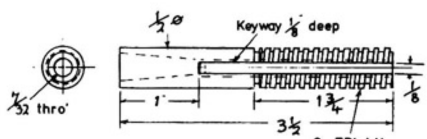
TAILSTOCK BASE



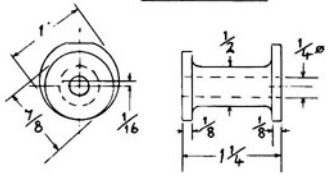




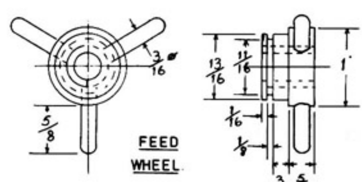
BARREL HOUSING



T/STOCK BARREL

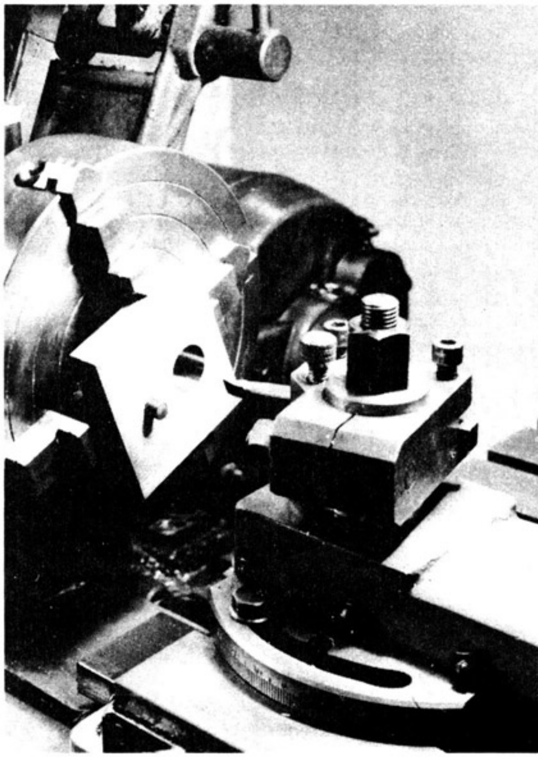


SPACER



FEED WHEEL

Fig. 8. Boring the pair of plates for the tailstock body.



up operation. Pop the test bar back in the mandrel bearings for this so that the longest possible length overhangs the bed, and slide the tailstock base on to the bed clamping it to the bed under the outer end of the bar. If you now place the body on the base and try to slide the housing over the end of the test bar, the bore of the housing should be distinctly too high to let this be done. The lining up therefore consists of gradually reducing the height of the bore by filing down the under edge of the end plate until the housing will slide comfortably over the end of the bar. Both end plates have to be treated, and if you do both together, try the fit from time to time with the body reversed, i.e., trying the counterbored end of the housing over the bar first, so as not to get one end too low accidentally. I found it a convenience in this operation having the plates still square, as the whole body unit could be gripped in the vice so that one plate acted as a guide to filing the edge of the other one flat.

When the body on its base will slide smoothly over the end of the bar without deflecting it up or down at all, you can reckon the bore of the housing is about right—in the horizontal plane, anyway.

One of the few jobs left now is the final shaping of the plates. This is purely sawing and filing to shape—and provides a little exercise as a change from lathe work! Another little job that could be done now in readiness is cutting down a 2 in. long $\frac{1}{4}$ in. bolt to $1\frac{3}{4}$ in. long for the spacer. As it is tapped into the back plate there is no need for a nut, and it is much neater flush with the plate on the outside. Having it flush will be handier, too, when it comes to fitting the feed wheel keep plate.

All the body pieces could now be

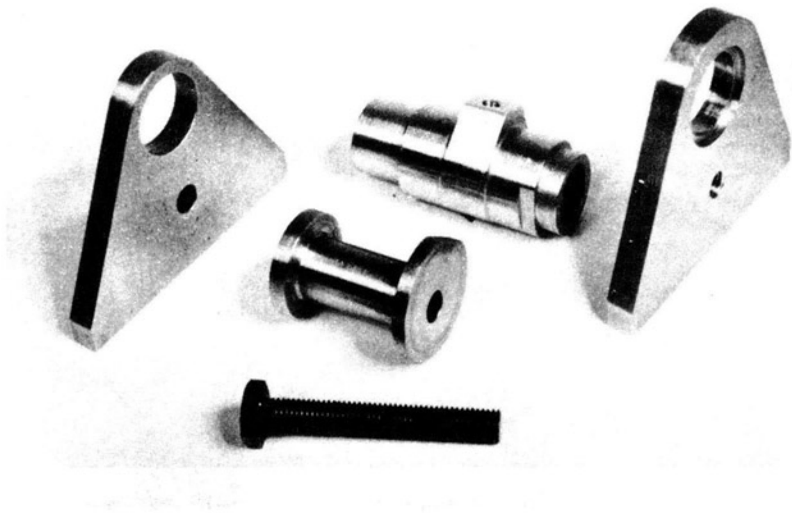
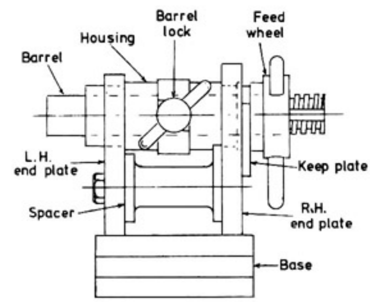


Fig. 9. Components of the tailstock body, ready for assembly.

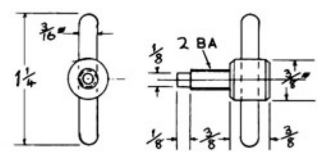
assembled for keeps. Prod a bolt through the spacer and screw it into position on the back plate finger tight. Offer up the housing to the hole in the back plate, turning it and the spacer so that the locking flats match up. Press the housing right home into the plate in the vice. Remove the spacer and pop the front plate over the nose of the housing. Reposition the spacer and thread through the shortened belt, running it into the back plate. See that the bottom edges of the plates come exactly parallel and press the plate right home; pull the bolt up tight and check that its end is flush with the outside of the R.H. plate.

The next stage is fixing the body down to the base, at the same time lining it up to the test bar in the vertical plane. Position the base under the end of the bar, slide the body on to the bar over the base and adjust its position on the base to show equal amounts of base projecting either end of the body. Hold the body down firmly on the base and scribe lines on the base all round the bottom edges of the body plates. This gives a clear indication of where to locate the four holes in the base for the holding screws. Mark out the positions for these on the base and drill them 2 B.A. tapping size. Fit body and base back again on the bed and test bar, locate the body exactly between the scribed lines and clamp the two together. The best way of doing this is to slip a short length of flat bar between housing and spacer, and fit clamps over the ends of this and under the edges of the base. Carefully slide the whole thing off the bed and spot through the holes in the base on to the under edges of the body plates. Remove the clamps, drill the spotted holes in the plates 2 B.A. tapping size, open up the holes in the base to 2 B.A. clearing, and countersink them underneath the base. Watch that you DO get them underneath! You may have to remove the guide strips for this, to accommodate the countersink.

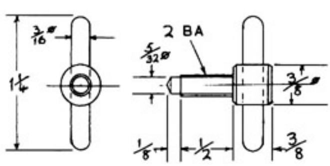
At first glance, the tapered shape of the body plates makes it look rather awkward to hold to drill the screw holes



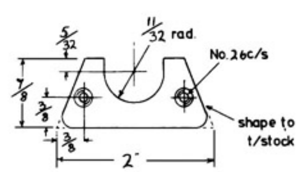
TAILSTOCK ARRANGEMENT.



BARREL LOCK SCREW



BED CLAMP SCREW



KEEP PLATE

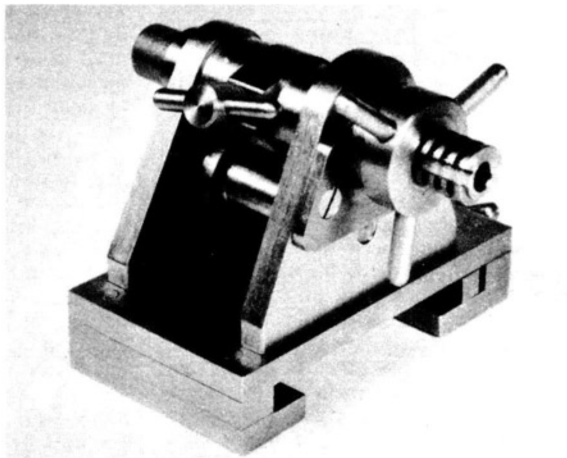


Fig. 10. The complete and finished tailstock

squarely in all directions. However, it is quite easy in the lathe. Mount the body on the vertical slide with the slide table nicely square to the chuck face or face-plate. You can then hold the body comfortably with a single bolt through the bore of the housing, with the surface of the R.H. plate against the slide and a piece of paper between it and the slide table to prevent any slip. Run the holes about ½ in. deep and tap 2 B.A. Assemble the body to the base and check that there are no burrs round the countersinks nor bruised screwdriver slots on the screw heads to prevent it sliding smoothly along the bed. Re-check with the test bar that all is in order still, and that should be that.

If you should find that something has moved fractionally and the complete tail-stock is reluctant to slip over the test bar, you can probably adjust things satisfactorily by attention to the nearside middle strip of the guideways "sandwich"; a tiny amount can be filed off if the tailstock appears to be fractionally over to the nearside, while if it is too far over towards the back of the lathe, a tiny slip of shim stock—or at the worst, a new middle strip—should fix things.

Next comes the tailstock barrel. If you can get hold of a short piece of precision ground mild steel rod, this will probably be an ideal fit in the housing with no attention needed at all. Failing that, and no good quality ordinary piece being a good enough fit, it will have to be turned down from the next largest size available —a straight and parallel ½ in. diameter throughout, 3½ in. long.

First job, face both ends and run a deep centre drill hole in both ends. These holes need to be accurately centred, so it is worth setting up the piece in the four-jaw and getting it running quite true for drilling them. The barrel is fed to and fro by the handwheel on a ⅛ in. pitch L.H. square thread, so the first step towards cutting the thread is to run in the $\frac{1}{16}$ in. wide and deep tool starting groove 1¾ in. from the chuck end. It is not proposed to detail the actual screwcutting operation and procedure on account of considerations of space, but if you are not too familiar with it you can probably find someone who will give you a hand, or you can read it up and practice a bit on some scrap ends. In any case, this piece will give you a little practice for when it comes to cutting the leadscrew! You will need exactly the same pair of lathe tools for that job as for this. In cutting this sort of thread many people prefer to start with the nut, and in this case the nut is the feed wheel. This is from a short piece of 1 in. round steel, and the smaller diameter and the groove for the keep plate should be turned first. Then without disturbing it in the chuck, drill and bore for the thread and screw-

cut that. Reverse in the chuck, face back to depth, and divide round the edge for the three holes for the spokes.

The spokes can be either pressed in, screwed, sweated in or fixed with Loctite. If you screw them, use a flat ended plug tap to run the thread right to the bottom of the holes, as there will only be few threads holding them. Incidentally, any of the components specified as "press fits" can equally well be made a close push fit and Loctited; the spokes in the feed wheel shown were so fitted and are prefectly firm and secure.

If you screwcut the wheel first, then the thread on the tailstock barrel will have to be finished to fit the wheel and this is a case of working towards a nice fit according to the feel of things when the wheel will just begin to show signs of screwing on. In screwcutting the barrel, grip the end $\frac{1}{2}$ in. or so of the portion to be left plain in the chuck and support the other end on the back centre—preferably a half-centre, if you have one. Aim for a nice smooth running fit between feed wheel and barrel.

Next comes milling the keyway along the barrel. There are two ways of tackling this; you can either end mill it, or use a Woodruffe type circular cutter. I chose to do it the latter way, clamping the barrel down to the cross slide mounted in a V-block. Whichever way you adopt, take care to get the barrel laying nicely square and horizontal across the axis of the lathe bed, else the keyway will not be straight and regular along the barrel. With the keyway cut, the lock screw could be made next, turning the end plain pip a snug fit in the keyway. Make it long enough for the threaded part of the screw not to foul the top of the square thread on the barrel. It is a simple turning and threading job needing no detailing, being just like the clamp screw for the back of the tailstock base.

At this point the barrel could be drilled right through. It is best to do this halfway in from each end to meet in the middle. The hole at the chuck end can be bored out for the taper socket at any time later on, when you have a pair of centres, then it can be bored precisely to fit the hard one of the pair. In fact, there will rarely be an occasion when the hole through the barrel will be essential; the most likely time is when using a tailstock dieholder for threading a longish length of small diameter rod held in the chuck. The hole through the barrel is shown as $\frac{7}{32}$ in. If you drill one much larger than that there will be some risk of making the bottom of the keyway too thin, and it might be possible to lock the barrel with the clamp screw tightly enough to dent or distort the keyway. Even though the bore through the barrel may be needed for some job only very rarely, it is worth drilling for the facility that it provides for tapping out the back centre and for cleaning out the socket. It is much better to run something through the hole and make sure that it is clear of chips than to take a chance that a blind hole is really clean. To pass on a useful tip, the ideal thing for cleaning out such holes is one of the "fluffy wire" type pipe cleaners.

There remains now only the feed wheel keep plate. This is shaped up from a rectangle of $\frac{1}{8}$ in. thick plate. Cut the piece wide enough to be able to include all the $\frac{11}{16}$ in. hole, and long enough to well overlap the sides of the tailstock end plate when in position. If you make it wide enough to be able to bore out the entire $\frac{11}{16}$ in. hole, it can be held in the four-jaw chuck for that job, which makes it an easier operation and tends to give a better finish to the hole than boring out an interrupted hole. With the hole bored, shape the top and bottom edges and lay the piece in position on the end plate. Scribe lines across it against the sloping edges of the end plate, which will show where to file it to size and also enable the two holding screws to be located. File to shape and mark in and drill the two holes 4 B.A. tapping size. Clamp back on the end plate in position, spot through on to the end plate, drill and tap the two spots 4 B.A. Open up the holes in the keep plate to 4 B.A. clearing, countersink on the outside, round off the corners for neatness, and that is that. Fit to the end plate with a couple of screws, adjusting their length so that their ends come just about flush with the inner surface of the end plate.

CHAPTER THREE

Saddle, Lead Screw and Bearings, Apron, Nut

ANOTHER component, very similar in many respects to the tailstock and one that is also carried on the bed, is the saddle, so this could be the next job.

The saddle is built up in exactly the same way as the base of the tailstock, and the method of production could be exactly as for the tailstock base. The saddle is $\frac{1}{2}$ in. wider than the base, but the drawings show all the requisite differences in respect of screw locations.

When the lathe is in use the saddle is almost continually being moved up and down the bed, so every care should be taken to obtain a nice smooth shakeless fit on the top plate of the bed. When the saddle is first assembled, moving it along the bed could show up the odd tight spot or two, and these should be painstakingly corrected before passing it as correctly fitting. Check that the lower strips in contact with the under edges of the bed do in fact contact over the greatest possible area, and gently take down any obvious high spots. These can be seen as small bright areas showing up after a few slides up and down the bed. Any conspicuous high spots showing up near the edges of the bed should also be dealt with.

The main difference between the tailstock base and the saddle is at the back of the saddle. The tailstock base is lockable on the bed by the clamp screw through the middle narrow strip at the back; here in the saddle the same strip is provided with three adjusting screws bearing on a gib strip to adjust the tightness of the saddle on the bed. With this arrangement the gib strip is not required to be stiff enough to clamp throughout its length on the bed from the pressure of just one screw, so it can therefore be thinner. In fact, it need be no thicker than is necessary for it to accommodate three shallow dimples drilled in it to receive the tips of the adjusting screws, so that it is carried along the bed with the movement of the saddle, behaving as part of it. The gib strip is therefore only $\frac{1}{8}$ in. thick.

Of the two strip assemblies embracing the bed edges, the front one is much the more important. The squareness of this middle strip across the top plate of the saddle fixes the squareness of the saddle as a whole across the bed, and the outer edges of the three strips comprising the front ways together form the surface on which is mounted the apron plate. So make sure in drilling for the assembly screws that the strips are clamped exactly squarely across the plate. Should their outer edges not all be dead level on assembly, they can be made so by a little gentle draw-filing, or a very light cut taken over the outer edges with a biggish end mill. These outer edges, too, should be nicely square across the saddle, else the apron will not be held parallel with the edge of the bed, and so the lead screw nut mounted behind the plate might be caused to bind a little on the screw. As regards the back strip assembly, this is not nearly so important as the adjusting screws will automatically locate the gib strip parallel to the front strip. Arrange the back strips to provide quite a slack fit when the gib strip is slid into position against the back edge of the bed.

To locate the dimples in the gib strip, after drilling the back strip tapping size for 4 B.A. adjusting screws, assemble the complete saddle on the bed, wedge or clamp the gib strip in position, and spot through the tapping holes on to the strip. Remove the strip and deepen the holes to about $\frac{1}{16}$ in. deep. Chuck each screw gently in the three-jaw, turn away the end two or three threads and point up the end to match the drill point angle. Tap the back strip and re-assemble, running the screws into position finger tight, fit locknuts, and cut off to length. Saw a

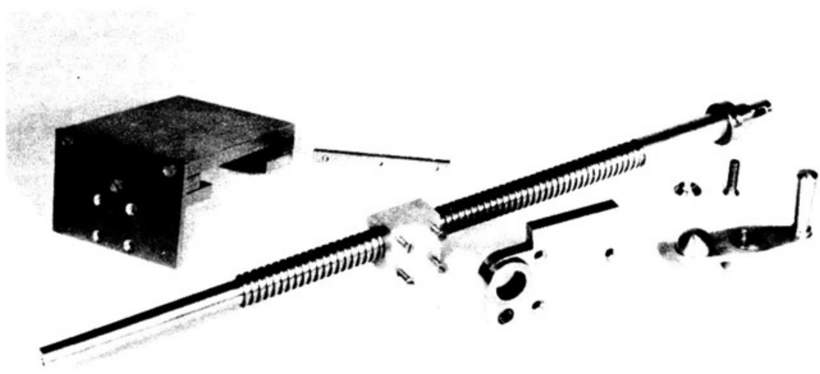


Fig 11 The saddle, lead screw and associated components.

fine screwdriver slot across the end of each, and that should be that. Do not bother to adjust the screws precisely at this stage, as the saddle will have to go on and off the bed a time or two yet.

The apron plate is a plain rectangle of $\frac{1}{8}$ in. thick plate, held to the front edge of the saddle by three 4 B.A. screws and drilled for the four 6 B.A. screws holding the lead screw nut. When you have the piece nicely squared up with its length matching the width of the saddle, mark off for the three 4 B.A. mounting screws and drill and countersink the front for these. Clamp it in position on the front of the saddle and check that it settles into position nicely square with the surface of the saddle. Spot through on to the edges of the pieces concerned, and drill and tap the three holes 4 B.A. While the four holes for the nut screws should come right if drilled now, it is safest to leave drilling these for the moment till their position can be positively checked from the nut itself.

The lead screw is another screwcutting job just like the tailstock barrel, although involving a much longer length of thread, of course. Start on the length of $\frac{1}{2}$ in. rod which will be the screw by facing the ends to length. Grip the rod in the chuck with only $\frac{1}{2}$ in. or so protruding and get it running quite true—falling back on the use of the four-jaw chuck if necessary. When it is running really true, drill in a fairly deep centre. Treat each end the same. Next, turn down the short $\frac{3}{8}$ in. diameter portion coming at the handle end. Reverse in the chuck and run down the longer $\frac{3}{8}$ in. diameter length at the other end, using back centre support. Withdraw a lot more rod out of the chuck till you can get a tool to bear on all the portion to be screwcut. Turn in the groove at the end of the thread wide enough to accept the tip of the screw-cutting tool with a trifle of width to spare. Screwcutting will be done from this end, with the tool running out over the longer $\frac{3}{8}$ in. diameter end. As it is a left-hand thread, the tool will be moving from left to right. If you turn the starting groove to leave the rod $\frac{3}{8}$ in. diameter at the bottom of the groove, you can tell from that when the thread is deep enough, and have an additional check at the other end when the tool finishes the cut just clearing the thinner length supported by the tailstock. Carry out the actual screwcutting in back gear; compared with the speed of the tool along a job when turning normally, in screw-cutting an 8 pitch screw the tool seems to fairly whip along the bed! On such a job, you can do with all the time you can win, to dab on cutting oil, watch the depth and finish of the cut, and all the other things that you will not have time to do if you take it too fast.

As a last operation on the lead screw, drill the centre at the short $\frac{3}{8}$ in. diameter end about $\frac{1}{2}$ in. deep 2 B.A. tapping, and tap 2 B.A. for an end play adjusting screw.

Incidentally, for those people proposing to build the job as a plain lathe, I would suggest making the lead screw the full length as shown. While its length is partly to bring the L.H. end reasonably near to the drive from the change wheels, the full length could have advantages for the plain lathe without the screwcutting gear. It would provide sufficient length of thread on the lead screw to be able to bring the saddle right up under a small chuck or very close to a faceplate, should that ever be required, and it would save drilling the front bed plate for the L.H. bearing where all the strength possible is useful—at what amounts to the gap.

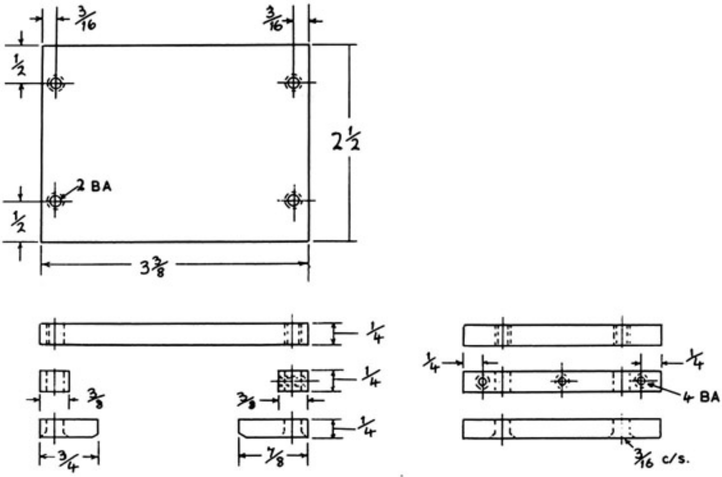
In fitting screws to nuts, it is generally reckoned preferable to adjust the size of the screw to fit the finished nut. However, in a job like this I prefer to finish the screw right out, and then adjust the fit by attention to the nut. If you cut the screw, using a tool the correct width at the top and take the thread to the right depth, there cannot be much wrong with the screw. As in this case, the nut is almost always a much shorter component than the screw and is therefore more easily altered a fraction over its short length than is a much longer length of screw. In adjusting the fit of a nut such as this too, it is much easier to take a tiny scrape out by pulling the lathe over by hand, which is something of a laborious business over the long length of screw. However, this is purely a personal preference which works for me, and other people will obviously get just as good results by other pet methods of their own.

The nut should be produced from some material which is a good bearing metal. Cast iron would probably wear for ever and a day, but good results should be forthcoming from something a little easier to work. Many lathes have nuts produced in zinc-based alloys, which give astonishingly long and good service. Most of the bronzes are obviously very suitable, but are rather tough when it comes to drilling and tapping. The nut in the lathe shown was made from a small block of dural; this is a good bearing material, is beautiful stuff to machine, and shows every sign of being a very suitable choice all round.

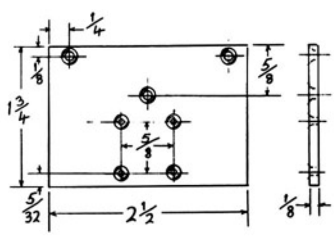
In making the nut, start by squaring up the block, facing all sides in the four-jaw. Leave it distinctly too thick—i.e., measured from front to back—until it is otherwise quite complete, then the front surface can be faced back to a good fit behind the apron plate when it is mounted on the screw. When it is squared up, mark in the centre for the screwcutting job, mount it in the four-jaw with the centre dot running true and drill through about $\frac{5}{16}$ in. Then bore it out to $\frac{3}{8}$ in. full with a small boring tool, both to ensure that the hole is basically true and with a good finish, and also to provide a shade of clearance over the bottom of the thread grooves. The bored block can then be screwcut just like the tailstock feed wheel, starting the tool well inside the chuck, of course.

When you have the nut a nice snug fit on the screw so that it runs smoothly from end to end, the next job is the lead screw bearing plate at the tailstock end. By the way, don't do what I did; I normally keep a train of change wheels set up for a slow self-act, for fine finish turning. After both screwcutting jobs I went to finish turn something else in the chuck and forgot that I still had the 8 pitch L.H. wheels set up. . . ! I was so taken aback at the tool charging briskly along towards the tailstock end of the bed that it was halfway there before I managed to smack the right knob!

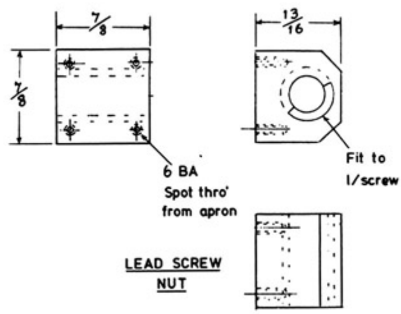
The bearing plate, like many of the other bits, is shaped up from a piece of $\frac{1}{4}$ in. thick flat. Mark out its shape, square up the top and back edges, and from them mark in the position for the bearing hole. Leave the other two edges unfinished for the moment, then you can grip the plate comfortably in the four-jaw for boring the bearing hole. This will give you a better finished hole more accurately located than just plain drilling, even if you have a $\frac{3}{8}$ in. drill. With the bearing hole bored, sawing and filing completes the shape. Clamp it to the end of the bed tightly up under the overhanging end of the top plate, and with the back edge level with the end of the side plate. Scribe inside the plate down the ends of the front bed plate inside and out, then you have a positive



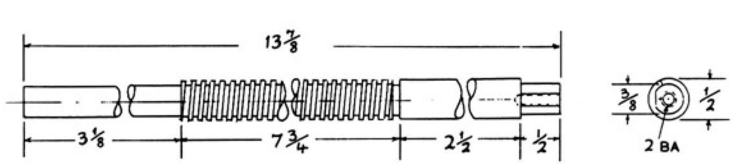
SADDLE



APRON PLATE



LEAD SCREW
NUT



LEAD SCREW. 8 T.P.I. L.H.

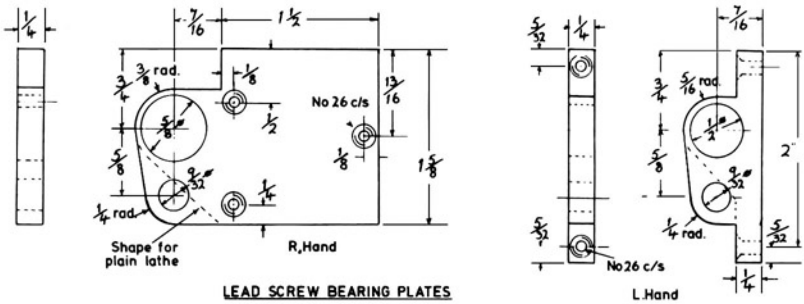
guide as to where to drill the plate for the two 4 B.A. fixing screws going into the end of that plate. As the bearing plate was level at the back, the back screw hole must come $\frac{1}{8}$ in. from the back edge. Drill all three holes 4 B.A. tapping, and clamp the plate back in position for spotting through on to the ends of the bed plates. Drill the three spots about $\frac{1}{2}$ in. deep and tap 4 B.A., opening up the holes in the bearing plate to 4 B.A. clear and countersink on the outside.

The $\frac{9}{32}$ in. diameter hole under the bearing hole can be drilled before the final shaping up. This hole carries one end of a $\frac{9}{32}$ in. diameter rod running the length of the bed under the lead screw, the rod being part of the lead screw clutch knock-out gear. This is a highly useful feature used mainly in screwcutting, so anyone building the lathe in its plain version will probably not need this feature, when the lower hole in the bearing plate can be omitted, shaping the plate round the one large bearing hole. The same goes for the two holes in the smaller L.H. bearing plate by the headstock, where the shape of the plate can be similarly adjusted to leave out the lower hole.

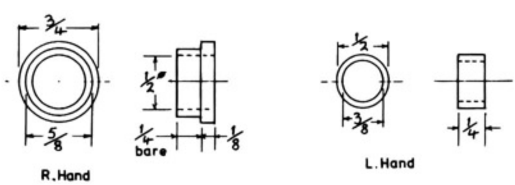
The bearing hole for the lead screw is fitted with an inserted bush, as the lead screw does a lot of revolving in its bearing. Here again, any good bearing material would be suitable for the bush, and as the mandrel bearings have cast iron bushes, the same material was deemed to be suitable here. The bush can be pressed or Loctited in, and this could be the next job. Make the bush a shade shorter under the flange than the plate is thick. This is so that a thrust collar on the lead screw runs on the surface of the bearing plate, and not on the smaller area of the end of the bush. As the bearing plate is steel, I made the collar of cast iron for the sake of dis-similar metals bearing against each other. If you make a steel one, provide a thin bronze or brass washer between collar and bearing plate. The flange of the bush is thicker than is necessary to withstand wear, and the idea here is to help stand the lead screw handle far enough away from the bearing plate to give ample working clearance. The operating handle is mounted on the short $\frac{3}{8}$ in. diameter portion of the lead screw end, with the $\frac{1}{2}$ in. diameter part running in the bearing bush. In setting things up, the collar is positioned so that the shoulder at the end of the $\frac{3}{8}$ in. diameter is just below the outer surface of the bush flange, then the boss of the handle runs against the bush flange. A 2 B.A. screw in the end of the lead screw adjusts the end play of the lead screw in the bearing.

The smaller bearing plate at the headstock end of the bed is another drilling and shaping job from the $\frac{1}{4}$ in. plate, and here again it will be useful to employ the "too deep for a start" technique. In this case, make the plate so that the bearing hole comes a fraction too far away from the bed, then its contact edge with the bed can be taken back gradually till the lead screw lays exactly parallel with the bed. Like the R.H. bearing plate, the hole for the lead screw bearing is bushed, but leave fitting the bush till the very last; by doing this you can once again use the silver steel test bar for lining up the lead screw. The tailstock end bearing is bushed down to $\frac{1}{2}$ in. and the unbushed headstock end bearing hole is $\frac{1}{2}$ in. diameter for a start, so the bar will fit in both bearing holes at this stage. With the L.H. bearing plate finished, the next step is to locate this so as to line up the lead screw accurately.

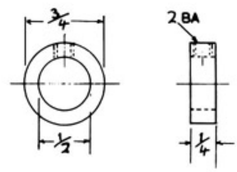
The L.H. side of the bearing plate comes $3\frac{1}{4}$ in. in from the end of the bed, so clamp the plate that far in, setting it by eye as near as you can "up-and-down-wise". Slip the test bar through both bearings and see how parallel it may be to the front plate. There will only be some $\frac{3}{16}$ in. space between the bar and the bed plate, which rules out the use of calipers for checking. However, you can get quite a close idea of the position by using number drills as gauges, using them as feelers between the two. If you want to be rather more precise, using the nearest small drill together with feeler gauges will get things really spot on. Gentle flat filing, a little at a time, will bring the bearing plate back to the right position. When it locates correctly in that plane, check with calipers between the



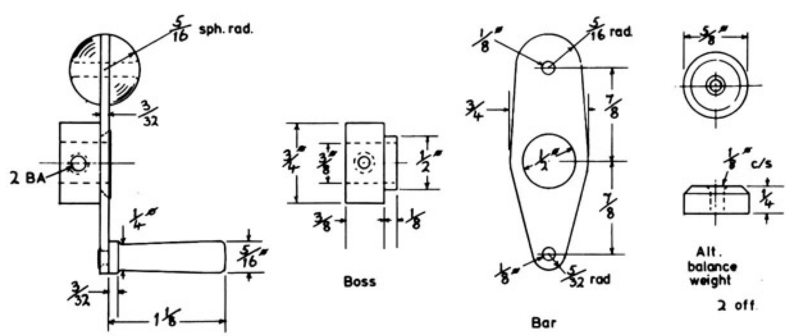
LEAD SCREW BEARING PLATES



LEAD SCREW BEARING BUSHES



THRUST COLLAR



LEAD SCREW HANDLE.

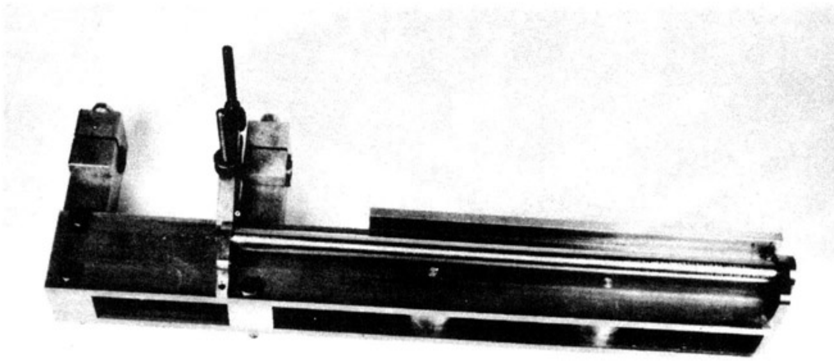


Fig. 12. Test bar set up for aligning the lead screw bearings.

top of the bar and the underside of the top plate, adjusting the clamped bearing plate fractionally up or down till its position checks as correct that way, too. When it is just right, tighten the clamp or clamps and spot through holes for the fixing screws, drilling and tapping the two marked spots 4 B.A. The plain unflanged bush can then be fitted in the bearing hole, when on assembly the lead screw should run smoothly in its completed bearings.

The end of the lead screw should protrude about $\frac{1}{8}$ in. through the L.H. bearing. Resist the temptation to cut this back, as it will be wanted for the clutch gear. Plain lathe builders can yield to the temptation if they like, as they will not need the clutch gear.

Things are now all ready to come back to the apron plate and take in hand anchoring the lead screw nut. Feed the lead screw through the R.H. bearing an inch or two, thread on the nut, and run it along to about the middle of the screw. Slide the screw further along until it runs in its bearings and move the saddle along till one edge of the apron is touching one edge of the nut. Turn the nut on the screw until its front contact face is parallel with the surface of the apron and scribe down the end of the nut against the edge of the apron touching it. This will show up just how much has to come off the face of the nut to allow it to slide behind the apron. Remove the nut and face this amount back in the four-jaw. Stop when you can just see the scribed line; it is better to take two bites at it than to take too much off for a start. If you do happen to overshoot so that the nut has some clearance behind the plate, this can be taken up with a square of shimstock or piece of thin card.

When it feels right locate it on the screw behind the apron, adjust its position centrally and mark out and drill the four screw holes in the apron. Wedge something lightly between the nut and the front bed plate and spot through the four holes in the apron for the screw holes in the face of the nut. Note that these are 6 B.A., and not the familiar 4 B.A. If the nut should happen to turn out deep enough to show the odd edge below the bottom of the apron, face back the bottom till this cannot be seen, just for neatness sake.

The last component involved here is the operating handle, and there are several alternatives possible for this. A plain wheel with one or two handles is very convenient, and has the advantage that the edge of the wheel can be graduated in thousandths, indicating saddle travel. The small size of this lathe means that the wheel would have to be of very small diameter if the tailstock is to be slid straight off the bed at any time; furthermore, its small size would mean that the calibrations would be so close together as to be almost useless for quick and easy reading. Correctly shaped balanced ball handles as fitted to larger

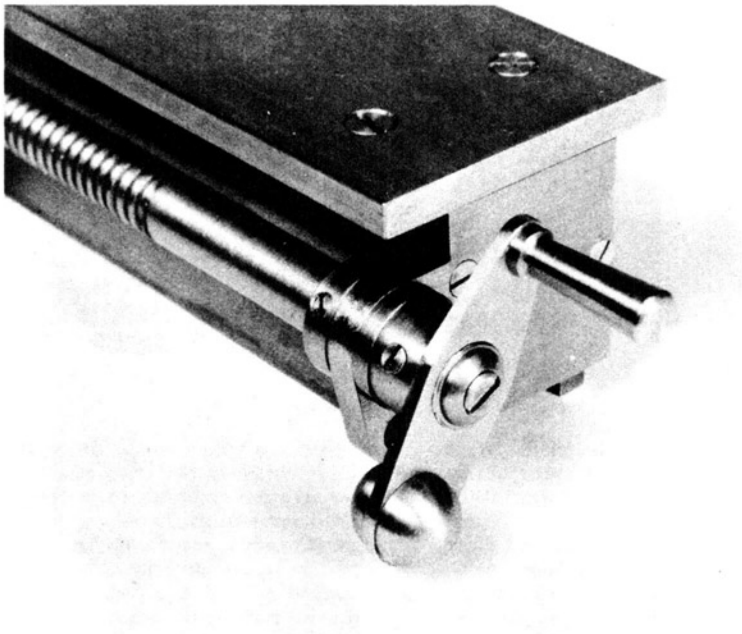


Fig. 13. Assembled lead screw, tail end bearing, and simplified balanced ball handle.

lathes would look nice and be equally nice to use, but these are by no means easy to turn successfully. The handle shown was evolved as an acceptable version of the ball handle, but one that is very much easier to make than the "proper" three-ball version. This is obviously something that builders can please themselves about, fitting whatever they most fancy, but making the type shown is described should it be decided to keep to what has been found straightforward and satisfactory.

The main point about whatever type of handle is fitted is that a $\frac{3}{4}$ in. diameter face should be provided to bear against the bearing flange. For this reason the boss of the handle is from a stub of $\frac{3}{4}$ in. round rod. The bar across it is from a $\frac{3}{4}$ in. wide strip of $\frac{3}{32}$ in. thick mild steel, drilled at one end for the handle grip and at the other for the balance ball. The bar is drilled centrally $\frac{1}{2}$ in. diameter and countersunk lightly on the outside. The boss is turned down to $\frac{1}{2}$ in. diameter for a distance slightly greater than the thickness of the bar. and the ring of $\frac{1}{2}$ in. boss protruding through the bar beaten down into the countersink. In other words, the boss riveted into the bar. The finger grip is similarly riveted in a $\frac{3}{16}$ in. hole in the rounded end of the cross bar. I happen to have a fancy tool for turning curved shapes. so this was used to turn a nicely rounded end to a stub of $\frac{5}{8}$ in. rod, the end drilled and countersunk for a $\frac{1}{8}$ in. rivet, and the half-ball parted off. This done twice produce two half-balls, which when riveted either side of the bar made a neat-looking balancing ball. The rounded shapes could be produced by some freehand "knob twiddling" and a little filing in the lathe, or two simple cylinders would do the job equally well. If plain cylinders are used, they could come down to $\frac{1}{2}$ in. diameter, as they would contain slightly more metal than does the same diameter ball, and so would weigh more. The boss is tapped 2 B.A. for a grub screw to lock the handle on the lead screw.

The collar on the inner side of the

bearing also has a 2 B.A. grub screw, and the location and fit of the collar and handle are set up as follows:

First file a flat about $\frac{3}{16}$ in. wide on the $\frac{1}{8}$ in. diameter end of the lead screw. Pop the screw through the R.H. bearing, thread on the collar and lead the screw through both bearings till the shoulder at the $\frac{1}{8}$ in. portion is just inside the bearing flange. Slide the collar tightly up against the inner side of the bearing plate and spot through the grub screw hole on to the lead screw. Remove the screw and drill the spot $\frac{3}{16}$ in. diameter about $\frac{3}{32}$ in. deep. Replace the screw and collar, tightening down the collar grub screw into the shallow hole to lock the collar on the screw. Fit the handle, run its grub screw lightly down on to the flat, and fit a 2 B.A. screw and washer in the tapped hole in the end of the lead screw. Tighten the screw gently, edging the handle towards the bearing flange till all the end play is taken up but the handle can turn smoothly. At that point tighten down the handle grub screw, so locking the handle.

The end screw and washer in the lead screw can be of any sort, but I fitted a thick washer, countersunk to accept a screw flush, so as not to catch the fingers. The washer can be bevelled or rounded as shown, to further the general suggestion of a ball handle.

CHAPTER FOUR

Feet, Cross Slide, Top Slide, Toolpost

THIS would be a convenient point, before getting the driving gear fitted up for the lead screw, to make and fit the feet. Having made and fitted them to make sure that they fit as intended, they could be left off during the remainder of the jobs that entail handling and fitting components to the bed. Mark each one as a reminder of where it goes.

The two brackets for the back gear are shaped up from pieces of 1½ x 1½ x $\frac{3}{16}$ in. bright steel angle, and this is very suitable material for the feet; both brackets and all four feet can comfortably be produced from a 12 in. length of the angle. The feet are the least precise components so far as size is concerned in the whole lathe, so if material is short, angle of somewhere near the size mentioned would probably do just as well.

Each foot is merely a 1 in. length of the angle, attached by two 2 B.A. countersunk screws to the inner side of the bed side plates. Check that the angles are reasonably square, and if not, make them so before fitting. Clean up the surfaces nicely flat and drill the hole in one limb of each for the holding down bolts. Bolts ¼ in. diameter should be amply stout enough for the job. Mark on the side plates a vertical line on which the screw holes will come and centre pop the two holes on each. Drill these 2 B.A. clear and countersink to accept the 2 B.A. screws flush on the outside. Commercially produced angle very rarely has a true sharp internal corner, so round off the bottom inside edge of the bed side plates just where the feet will come, so that the feet will seat snugly against the inside surface and the bottom edges of the plates. This is easier than trying to make the same adjustment on the angles. Clamp each foot in turn in position behind the side plates, symmetrically about the fixing holes, and spot through the holes on to the angles. Drill and tap the spotted positions 2 B.A. Carry out a trial fit-up of the feet, cutting back the screws if necessary so that they are about ½ in. long overall. And that is all that is involved in making and fitting the feet.

So coming back to some of the more precision pieces, the cross slide could be the next item. There is not sufficient depth available between the top of the saddle and the centre height for both the cross slide and the top slide to be built up of strips like the saddle, so both these slides feature the conventional 60 degree dovetail arrangement, which keeps each slide down to only two thicknesses of plate.

Start the production of the cross slide with the base plate. The main feature of this is the two accurate angled sides, which must be exactly parallel for smooth working. The first step is to square up the rectangle of ¼ in. plate to the sizes shown, getting the long sides nicely parallel as a necessary preliminary to forming the angles. The 60 degree angles can be produced in a number of ways; in the first plain lathe of this type I ever built, they were shaped by filing throughout, and the result was quite satisfactory. If you produce them by filing, set a bevel gauge to 60 degrees and use this frequently during the filing to check that the correct angle is being maintained. If you have the long sides of the plate nicely parallel for a start, you can use what will be the wider edge as a guide to the straightness of the filing. If you prefer to machine the angles for a start, here again there are various ways of doing it. One way is to clamp the plate vertically on the vertical slide, set the slide round to 30 degrees to the faceplate, and then fly-cut the plate edge with a stubby cutter mounted on the faceplate at a radius sufficient to sweep the whole length of the plate. Another way is to make up some sort of angled fixture to hold the

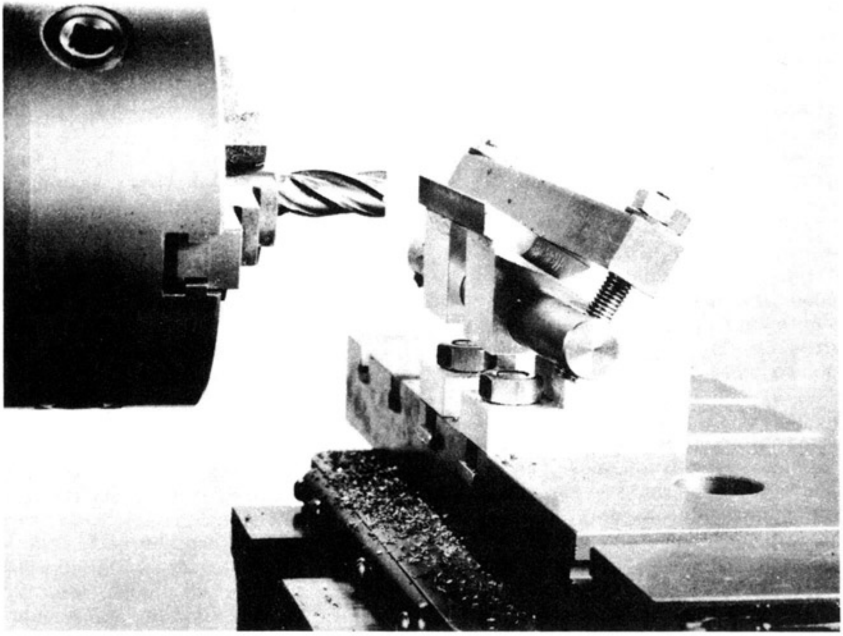


Fig. 14. End milling the 60 deg. angled edge on the cross slide base.

plate down on the cross slide, for end milling from the chuck. This is in fact what I did. The photograph shows my arrangement, produced from a couple of blocks of dural. This is somewhat more elaborate than is strictly necessary perhaps, but as I intended making a number of dovetail slides for another purpose, it was thought worth while to make the adjustable fixture shown, which can accommodate a wide variety of lengths and widths of material. A much simpler version could consist of merely an accurately angled hardwood block bolted down to the cross slide, and on which the plate to be dealt with could be clamped.

Whatever the method adopted for machining the angles, the final finish filing should be by smooth draw-filing, and the final filing should be left until the top part of the slide has been made, as any tight spots which show up when this is first fitted to the base can then be corrected at the same time as the final finishing.

The base plate has a $\frac{5}{16}$ in. wide slot down its centre to clear the feed screw, the screw being tapped through the end of the plate at one end of the slot. The slot can be end-milled out, or sawn out with a small saw from a $\frac{5}{16}$ in. hole at each end. It will be obvious that the tapped screw hole needs to be square in all directions, and to help to ensure this I drilled the hole in the lathe. Mark out and centre pop a spot exactly in the middle of both ends. Mount an old tail centre in the tailstock and a small centre drill in the three-jaw. Hold the plate between the points of centre drill and tail centre, and feeding the plate gently on to the drill with the tailstock feed, drill a generous sized centre hole in both ends. Change the centre drill for $\frac{3}{16}$ in. B.S.W. tapping size (No. 28) and drill the hole through into the end of the slot. Note that the thicknesses left at each end of the slot are not the same, and the screw goes through the thicker end. Start a $\frac{3}{16}$ in. Whitworth taper tap truly into

the hole by gripping it in the chuck like the drill and supporting the other end of the plate on the tail centre. Run it in a turn or two and then finish tap by hand in the vice. The $\frac{3}{16}$ in. Whitworth thread having 24 threads to the inch is a bit finer than might be ideal, but it is the coarsest pitch thread that can be accommodated in the $\frac{1}{4}$ in. thickness of the plate.

To finish the base plate there remains the pair of screw holes used for holding it down to the saddle. Two $\frac{1}{4}$ in. B.S.F. screws are used for this, and you will have to turn up two special cheese head screws for this. Mark off and centre dot the two places for these. I drilled these from the chuck with the plate clamped to the vertical slide, as when each is drilled through, the hole is counterbored $\frac{1}{8}$ in. deep, square bottomed. This is best done with an end mill or home-made slot drill immediately on going through with the $\frac{1}{4}$ in. drill. The hole coming next the headstock is counterbored $\frac{3}{8}$ in. diameter, and houses a screw with a head this diameter. The other is counterbored $\frac{1}{2}$ in. diameter, but its screw is $\frac{3}{8}$ in. diameter, the same as its fellow. This is to allow for setting the travel of the cross slide exactly square across the centre line of the lathe. When everything is finished to the point of being able to use the lathe, a trial cut is taken across a fair diameter and the result checked for flatness. It may well be that the flatness could be improved upon, in which case the hole in the larger counterbore can be drawn over a fraction to allow of the cross slide being edged round a trifle, the larger counterbore still accepting the screw head in the drawn-over hole.

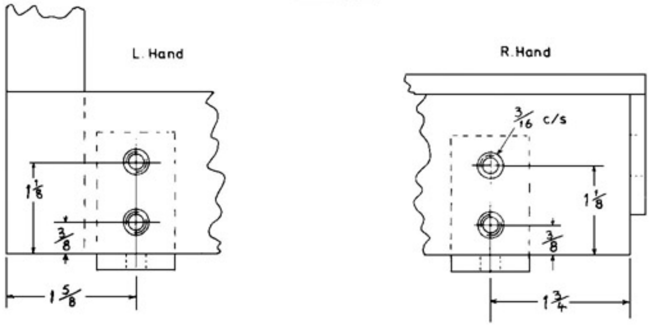
The two screws are plain turning and threading jobs, making the threaded part a length that just clears the bed when screwed home through the cross slide base into the saddle, and the head shallow enough for the top slide itself to pass over it without touching. The screwdriver slot can be sawn in by hand. Leave drilling and tapping the saddle for the two screws until the slide is finished right out, then the holes can be accurately spotted through.

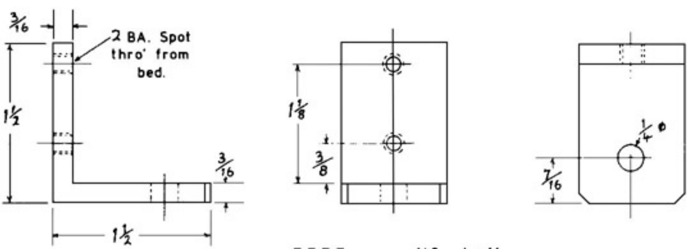
The moving top of the slide starts as a $3\frac{3}{4}$ in. length of the $2\frac{1}{2}$ x $\frac{1}{4}$ in. plate. Clean up the ends smooth and square. The dovetail strips are the same length and are $\frac{1}{4}$ in. wide on the narrow sides which bed down on the top plate. These can be produced from $\frac{1}{4}$ x $\frac{3}{8}$ in. strip, or from strips sawn from an odd piece of wider plate. Take the same care with the angles on these as with the base, keeping the edges accurate as to angle and straight. These can be finish filed true as they are produced. Mark off for the three fixing screw holes on the narrow face, drill 4 B.A. clear, and countersink on the wide face—i.e., what will be the underside when they are assembled. Note that these holes are not located symmetrically along the strip, there being one nearer the end which will always be taking some load. This has the effect at this stage of making the strips "handed", and if one strip should be slightly better than the other, make the best one the L.H. one nearest the headstock. Clamp the L.H. strip in position along one edge of the top plate, getting it level all round, and spot through the holes for the 4 B.A. tapped holes for the three screws securing it to the top plate. Drill and tap where spotted and screw the strip to the plate, cutting the screws down roughly to length.

To locate the other strip we need the gib strip for inclusion, so that is the next piece. Conventionally gib strips are of mild steel and as they normally work against cast iron dovetails, we get the benefit of different metals rubbing against each other. As the working surfaces here are of mild steel it could be useful to have the gib strip of something other than mild steel. Brass would probably be very suitable, but in the slide shown the strip is of dural. This can sometimes tend to pick up on sliding contacts, but a burnished surface will prevent this. The strip can be a full $\frac{1}{16}$ in. thick; 16 S.W.G. is a few thousandths thicker, or it can be filed down from $\frac{3}{32}$ in. material. Both long edges of the strip are angled off to 60 degrees so that the full width of the strip is brought to bear on the working surfaces. Make it a shade narrow so that it does not rub on the surface of the saddle when the slide is moved.

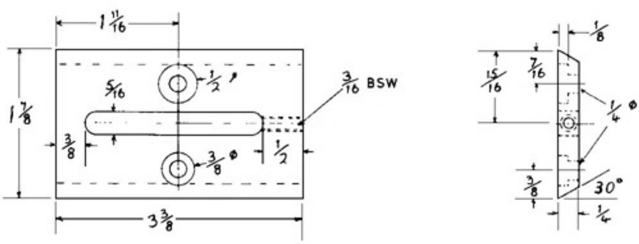
Place the base plate in position against

LOCATION OF FEET

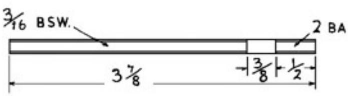




FEET M.S. 4 off.

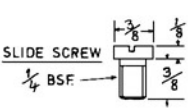


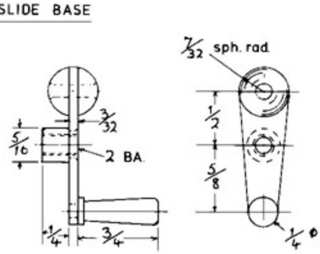
CROSS SLIDE BASE



FEED SCREW

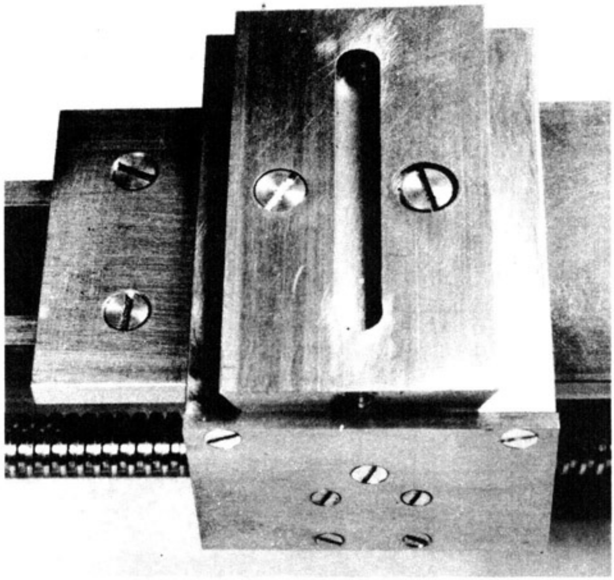
SLIDE SCREW





FEED HANDLE 2 off.

Fig. 15. Cross slide base mounted on the saddle.



the fixed side strip, add the gib strip, and against that the second side strip. The outer edge of the strip should coincide with the edge of the top plate; if it is fractionally inside the plate edge, insert a strip of paper next the gib strip to level things up. If the side of the strip overhangs the edge of the plate, thin down the gib strip till things do come level. Clamp the side strip in position, spot through for the screw holes as before, and drill and tap for these. Mark off and drill for the three 4 B.A. gib adjusting screws. Re-assemble the pieces, including a thickness or two of paper between the base and the gib strip so that the gib strip is held tightly against the side strip. Run the tapping drill back through the adjusting screw holes so as to drill dimples in the gib strip opposite the adjusting screw holes. Remove the side strip, tap the 4 B.A. holes, point up three short lengths of 4 B.A. screw, and try it all together with the gib strip held in position by the tips of the adjusting screws. Locknuts are one size smaller than standard—in other words, 5 B.A. tapped out 4 B.A. Adjust the length of the screws so that they are all the same on the outside and saw in fine screwdriver slots. The locknuts can be thinned down a trifle if preferred, but there is room to leave them full thickness.

With the slide pieces assembled, the base should slide smoothly right through the top plate assembly, equally tight throughout the travel. If it jams tighter one end, then the base is fractionally wedge shaped, and some gentle corrective filing is called for along one edge to correct it.

Next comes the front plate, and this is plain filing from $\frac{1}{8}$ in. thick strip or plate. Cut the piece slightly oversize, a nominal $2\frac{1}{2}$ in. long x $\frac{11}{16}$ in. wide. Mark off and drill for the four 6 B.A. fixing holes, allowing for just a trifle to come off the top edge. Clamp the plate symmetrically on the front of the slide and spot through the holes on to the ends of the strips and top plate for the screws. Drill and tap these 6 B.A. and countersink the holes on the front of the plate. The bearing hole for the feed screw must come opposite the "nut" hole in the base, and the best way to ensure that it does is to jig the hole location from the tapped hole in the base.

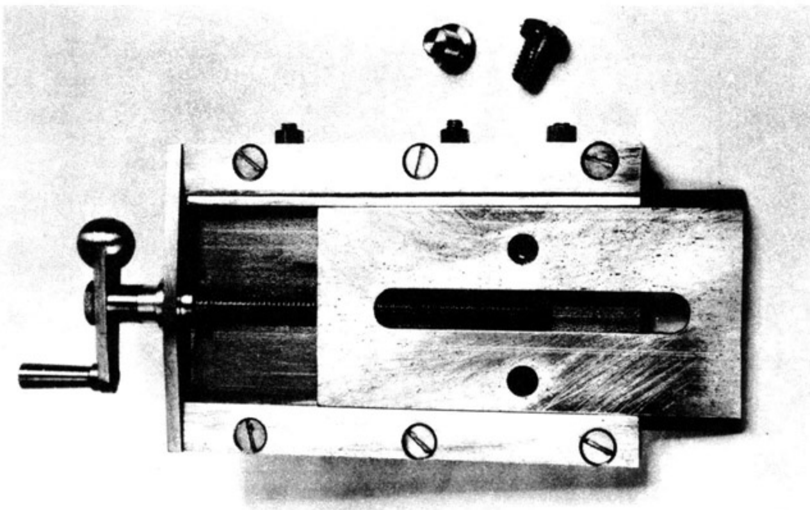


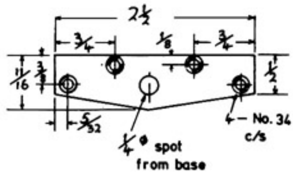
Fig. 16. Assembly of the completed cross slide, seen from underneath.

Run a $\frac{3}{16}$ in. Whitworth thread on the end of a piece of $\frac{3}{16}$ in. silver steel rod and turn a sharp point on the threaded end, like a centre punch. Cut it off to produce about an inch of screwed rod. Harden this right out. Run it into the tapped hole in the base, point outwards, and slip the base into the slide so that the point contacts the inside of the front plate. With the whole thing end up on the bench give the front plate a gentle bump with a piece of wood, and you have a centre pop mark truly in the centre of the feed screw hole. Before drilling the hole mark out the curve of the lowest point of the plate with dividers centred in the punch dot, then open up the hole with a centre drill, going right through with the $\frac{1}{4}$ in. drill. Keep the screwed jig punch for use with the top slide.

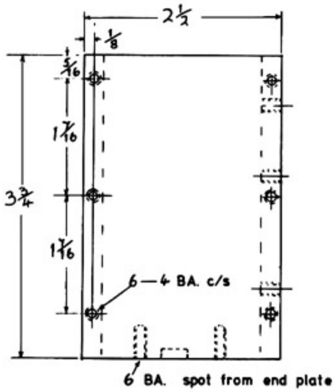
Screw the plate back into position and mark round for the final shape and size. Take the top edge fractionally below the surface of the top plate so that it does not impede slewing the top slide round to overhang, should you ever need to do so.

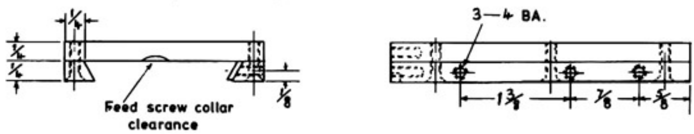
The feed screw itself can be merely a length cut from a piece of $\frac{3}{16}$ in. Whitworth studding, but on the whole it is worth while to make one specially for the job. This for two reasons; one is that the operating handle is threaded on the end of the screw for adjustment, and this is more precisely carried out with a finer thread than Whitworth. The other is that by threading the main length of the screw yourself, the die can be adjusted to cut a little big for a start, and then adjusted down to finish up with a "tailor-made" thread that is a really good fit in the tapped hole. The screw carries a bronze collar tight on the screw which runs in the $\frac{1}{4}$ in. hole in the front plate, and this collar can be tapped $\frac{3}{16}$ in. Whitworth and run tightly up to the end of the business part of the thread. Make the sleeve part of the collar a fraction shorter than the thickness of the plate, so that end play on the screw can be closely adjusted by the handle position. Between the handle and the front plate, taking the thrust of the screw, comes a distance collar either of bronze or dural. This not only gives the smooth running different metals again, but serves to stand the handle further away from the front plate making for a more convenient operating position.

The operating handle for the slide is made in exactly the same way as that for the lead screw, with dimensions adjusted

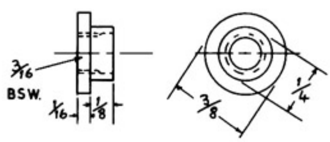


END PLATE 1/8 thick

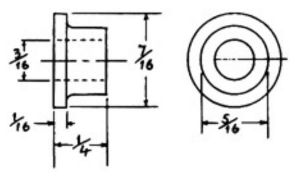




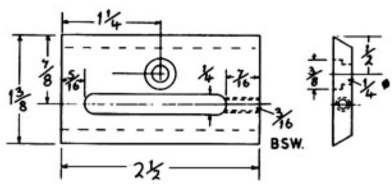
CROSS SLIDE



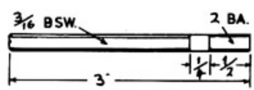
FEED SCREW COLLAR



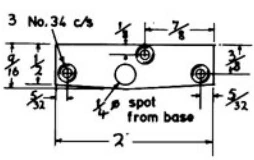
FEED SCREW SPACER



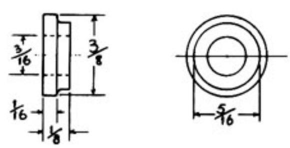
TOP SLIDE BASE



FEED SCREW



END PLATE



FEED SCREW SPACER

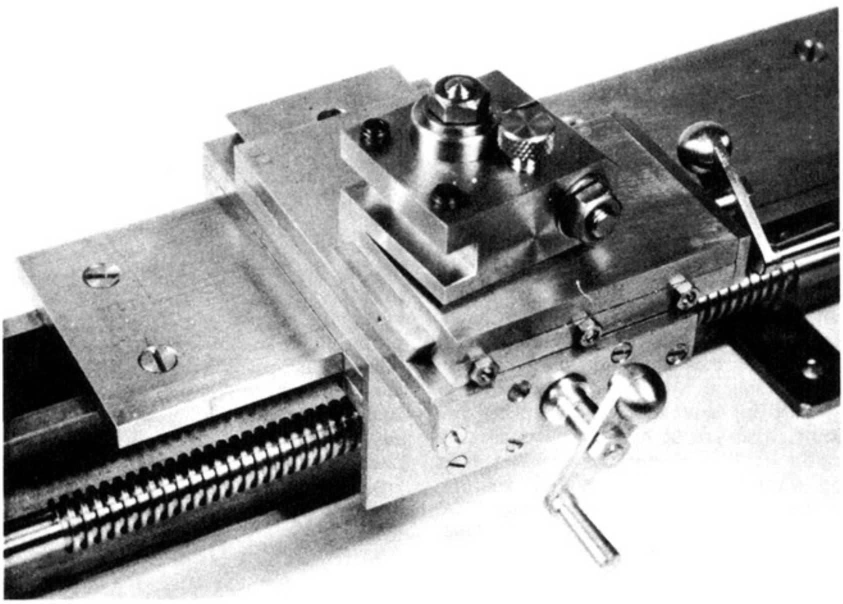


Fig. 17. Completed toolpost, cross slide and saddle mounted on the bed.

to produce a slightly smaller version. Make two of all the bits, as an exactly similar one is needed for the top slide. In making the boss, instead of a plain drilled hole having a grub screw in the side, the boss itself is tapped 2 B.A., so drill No. 24 and tap 2 B.A. Leave it a trifle long, then should any slight burr result from riveting on the cross bar, the boss can be mounted on a long 2 B.A. bolt—or short piece of studding—held in the chuck, and the end re-faced. It can be reversed before attaching the handle grip and balance weights to face up and neaten the riveting on the outside. Use the same piece of screw to thin down a standard 2 B.A. nut to about $\frac{3}{32}$ in. thick for a locknut on the front.

Last little job; if you assemble the screw to the front plate and go to fix this in position, you will find that the collar on the screw fouls the front edge of the top plate. Slip the base into the slide, run the bare screw an inch or two into its hole in the base and pull the slide outwards again. When the collar contacts the plate edge, mark round it where it needs a clearance crescent. Clip the top on the vertical slide and with either an end mill or slot drill mill out this clearance deep enough and of large enough diameter to provide clearance all round the collar. Re-assemble and check that the side strip screw heads are just below the surface of the strips, that the side strips do not rub the surface of the saddle when the base is tight down, and that the base beds down on the saddle with no rock. Clean down the ends of the side strip screws flush with the top.

Unwind the handle till the base protrudes from the back end of the slide $\frac{1}{2}$ in. or so. Locate the slide in position on the saddle, bringing the L.H. side level and even with the L.H. side of the saddle, and the end of the base plate level with the back edge of the saddle. Clamp down at the back edge in that position, then without moving anything, carefully wind off the top plate complete and spot

through the two fixing down holes on to the top of the saddle. Remove the saddle, drill and tap the two spots ¼ in. B.S.F., re-assemble and check the length of the holding down screws when tightened down.

With the cross slide complete, the whole job is repeated in pretty much the same way for the top slide. This is slightly smaller than the cross slide so that dimensions and screw locations are different, but it is made in just the same way, so needing no detailed procedure repeated. The top slide base is held down firmly to the cross slide by one screw only, and this is located to the side of the feed screw nearest the lathe centre line. The feed screw is accommodated on the nearside of the fixing screw for two reasons; (a) to make ample room for the screw, and (b) to bring the operating handle slightly nearer the operator over the nearside edge of the bed, making for easier accessibility of the handle. The single fixing screw makes it a simple matter to set the top slide over for short taper turning.

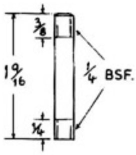
The handle is an exact duplicate of that fitted to the cross slide, and is fixed and adjusted in the same way. The spacer between the handle boss and the slide end plate need be only ⅛ in. thick here, and like the other one, can be either bronze or dural. The end plate is attached to the slide by only three 6 B.A. countersunk screws in this case, taking care that the middle one well misses the feed screw collar recess in the end of the top plate. 5 B.A. gib screw locknuts tapped out to 4 B.A. are needed again here, to ensure that their corners clear the top of the cross slide.

As with the cross slide on the saddle, check that the base plate beds down really flat and firmly on the cross slide, and that the undersides of the dovetail strips just clear the cross slide surface.

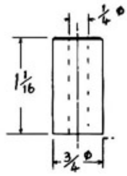
To complete the slides assembly, there remains the toolpost mounted on the top slide. The advantages of this type were mentioned in the introduction and builders can obviously choose whether to fit one of this type or not. If you happen not to have had experience of this type, I would like to urge that the work involved in making it will be found well worth while once you have tried it.

It starts as a block of mild steel 1½ x 1¾ x ¾ in., and I had to saw this out of a piece of 1 x 2 in. bar. Even if you have to do something similar, it will still be worth while! Face up all the sides in the four-jaw chuck so that the piece is nicely square and to size. Mark out for the big through hole for the pillar and re-chuck in the four-jaw to bore this out. Aim for a nice finish in the hole and a snug sliding fit on the pillar. Avoid making the fit slack at all, else you will have to use excessive spanner pressure on the clamp nut to grip it tightly enough on the pillar so that it is immovable. The pillar is merely a 1 in. length of ¾ in. diameter truly round rod, drilled through centrally for the holding down stud. If by any chance you have to turn down the piece for the pillar from something bigger, bore the hole in the block to nominal size first, then turn down the pillar to fit.

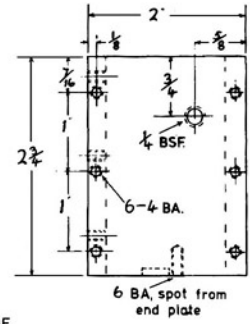
When the hole is bored, next drill the cross hole for the clamping stud. The stud is ¼ in. diameter, so the hole can be fractionally larger to provide ample clearance—say $^{17}/_{64}$ in. or letter G drill—and can be taken in to about 1⅛ in. deep across the block. Finish the hole through with No. 5 drill—¼ in. B.S.F. tapping size. The "large ¼ in." hole will nicely guide the tap truly for tapping the ⅜ in. depth of thread, and use a taper tap for all the tapping of this thread. The dodge here is not to run the tap right through to produce a full normal thread, but stop tapping when the outer end of the hole is just beginning to show a suggestion of a shallow thread. If you make the clamp stud in the normal way, the thread in the hole at this stage will not be deep enough to let the stud screw right home. When the stud is ready, the tap can be run slightly further through the hole, fractionally deepening the thread, till the stud can be screwed in very tightly so that its end comes flush with the side of the block. The stud is threaded up from a short length of ¼ in. rod and when you thread the end for the nut, make the stud about ½ in. too long at this end. Then when the stud comes to



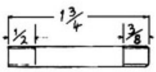
TOOL POST STUD



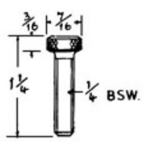
TOOL POST



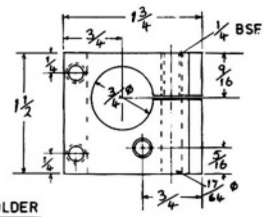
TOP SLIDE



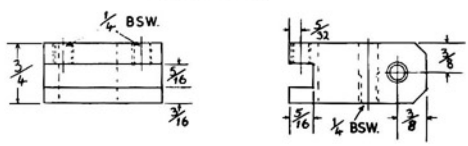
CLAMP STUD



HEIGHT ADJ. SCREW



TOOL HOLDER



be fitted, you run on a washer and the nut, grip the outer extreme end of the stud in the vice and screw it properly home. The extra protruding end outside the nut can then be cut off and the end of the stud filed off neatly close to the nut. However, do not fit the stud yet; the block needs to be split first to allow of it being clamped hard on the pillar.

The neatest way of cutting the slit is to saw it in the lathe with a slitting saw mounted on an arbor or stout bolt. However, a quite satisfactory job results from a little careful hand sawing, and the one shown was so cut. Mark the line of the cut on both the top and edge of the block and take care to saw dead on the line. The inevitable slightly ragged edge to the cut can be neatened up by very slightly chamfering the edges with a fine three-cornered file, and the result looks pretty well as good as a machined slit. When the slit is cut, clean out the swarf from the slit and hole and fit the stud.

Another drilling and tapping job comes next, for the hole for the height adjusting screw. Here again, the hole can be clearance size for some $\frac{7}{16}$ in. deep, leaving just $\frac{5}{16}$ in. or so to be tapped. This ensures a truly tapped hole, makes the tapping job that much easier, and saves wear and tear on the tap. Note that the thread here is the coarser Whitworth thread, as the faster action of the coarser thread in raising and lowering the holder up and down the pillar makes for easier use. The screw itself is turned from a short end of $\frac{7}{16}$ in. rod, with the head knurled for easy handling, and the thread run down to an almost slack fit in the tapped hole.

The tool slot in the holder shown was end milled all the way from the chuck, with the block clamped to the vertical slide. It could be formed by a cross hole running along the line of the slot and finish sawing and filing, or by filing from a line of shallow holes drilled in from the open side of the slot. Whichever way it is produced, aim for a nice flat "floor" to the slot, so that the tool will sit down flat and evenly in its slot. To complete the tool holding arrangements, drill and tap the two tool clamp screw holes in the top—Whitworth thread here again. Two $\frac{1}{4}$ x $\frac{3}{8}$ in. Whitworth grub screws make neat clamp screws, and the same advantages of the Whitworth thread apply here as to the height adjusting screw. A finer thread is quite unnecessary to obtain greater pressure on the tool; it need never be clamped down much harder than finger tight. In fact I have more than once finished a light turning job, then on going to change the tool, have found that I had inadvertently left the tool only finger tight!

Just as a last finishing off job, the top and bottom corners along the R.H. edge could be angled off along the line of the clamp stud. Filing would do this quite well, finishing off with a good surface from draw-filing. I end milled most of it off, then draw filed for the finish. This need not be done at all, of course, but it does add that little bit of neatness in appearance.

The drawings show the location on the cross slide for the hole for the pillar mounting stud. Make the bottom threaded end a close fit in the tapped hole in the slide, and make sure that the end of the stud does not stick through the slide to foul the base plate when screwed home.

It will be obvious that the $\frac{1}{4}$ in. plates from which the various slides are made are not thick enough to provide any tee slots. However, there is nothing at all to prevent anyone providing a pattern of tapped holes in any one of them to serve much the same purpose. A collection of these in the top of the cross slide could well be used for clamping work down for milling or fly-cutting from the chuck, while an extra one for the toolpost pillar in the top slide, further back nearer the front edge of the slide, might prove useful for turning or facing the larger diameter job while retaining the longest possible engagements of the slides. While these could be useful at times, the tendency should be avoided to finish up with a random and untidy collection of holes, which if carried to extremes would merely weaken the plate in which they were drilled.

CHAPTER FIVE

Mandrel, Pulley, Back Gear

THE mandrel and associated bits could well be the next things to tackle. If the back gear and screwcutting features are to be fitted, then it could be useful at this point to see about obtaining the necessary gears for both these functions.

The sizes of gears are normally referred to in terms of "Diametrical Pitch"—or D.P. for short—and these are all of 20 D.P. They are all of mild steel, having a thickness or tooth width of $\frac{3}{16}$ in. Such gears are commercial items available from a number of sources, and according to the maker, may differ slightly in some particulars from those used here as to thickness, whether provided with a boss, and so on. The general design of the lathe could be modified to make use of slightly different gears should these be the only ones available, or the gears could be modified in the way to be described. The gears shown had to be so modified slightly, but this is a quite straightforward operation and no snags should arise.

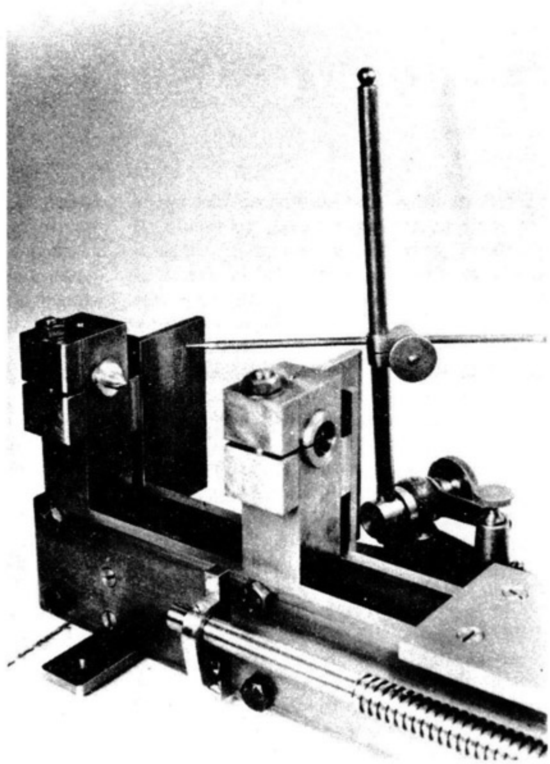
The back gear uses four gears, two each of 20 teeth and two of 50 teeth. The screwcutting set consists of eight gears; two of 20 t., and one each of 25, 30, 35, 40, 45 and 50 t. Thus the complete set comprises a total of twelve gears; four of 20 t., one each of 25, 30, 35, 40, 45, and three of 50 t. With the gears on order, there is plenty that can be done to forward the job while waiting for them to turn up! Those builders tackling the job as a plain lathe will not need any of the gears, of course.

Make a start with the mandrel itself. This is a component of some importance, so should have some care spent on it to make it as nice a job as you can produce. It is plain turning from a length of $\frac{7}{8}$ in. diameter mild steel bar. If some steel other than "mild" is preferred, by all means make it of that, provided it can be turned to a good finish. All the turning up to the screwcutting stage is done between centres, so face both ends of the bar bringing it to true length, and run in a deep centre at each end. The centre holes can be considerably bigger than would normally be provided for between centres turning, as they will be used at the end as a start for drilling right through the mandrel for the "hollow mandrel" feature. Deep drilling such as this operation calls for can be a bit tedious, but the clear way right through is well worth providing when it comes to turning a number of small items from rod.

When the mandrel is finish turned all except the screwing so that it is parallel, the right size, and of good finish, put it aside while you make the end play adjustment nuts. These screw on the outer end of the mandrel, bearing against the flange on the L.H. side of the headstock column. One of these is very much thicker than would appear to be necessary for just a nut. This is because the nut—the outer one of the pair—will later on be drilled for a pin protruding from the face to drive the first of the gear wheels comprising the screwcutting train. It also acts as a locknut, being locked against the thinner nut underneath it which bears against the flange. Builders of the plain lathe can make both nuts the thinner size. They could also reduce the length of the mandrel by 1 in. or so if preferred, as the extended tail to accommodate the change wheels will not be required. However, if the length of the mandrel is curtailed, it could be useful to leave it long enough still to accept a polishing mop, dividing accessories, or something similar on the extreme outer end.

The best way to make the nuts is to do the two together in one piece, treating this as a short cylinder to be faced, threaded, and then parted into two. Both can be machined from a $\frac{3}{4}$ in. length of $\frac{7}{8}$ in. diameter rod. Set up the lathe

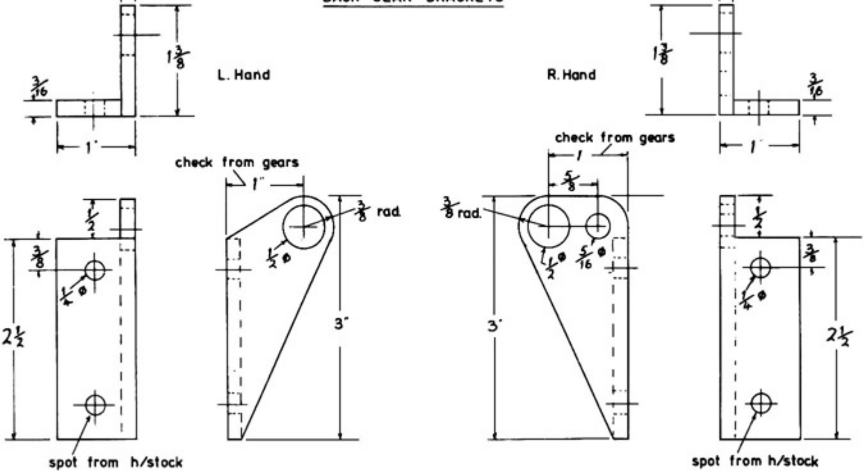
Fig. 18. Marking out the back gear brackets for the shaft bushes.

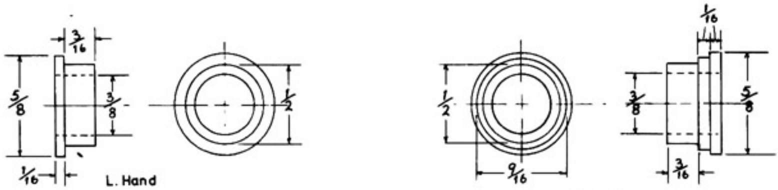


change wheels to screwcut 16 t.p.i., and after drilling through, screwcut the piece internally to nearly finished size. Finish off the thread inside by running a ½ in. B.S.F. tap through; this will size the thread and also shape it correctly. The point of making the nuts before threading the mandrel is that either (or both) of these can then be used as a gauge for the size and fit of the mandrel thread. The thread on the tail end of the mandrel is sized and shaped in a similar way by finishing it off with a ½ in. B.S.F. die, and when this has been adjusted to produce a nice fitting thread to exactly fit the nuts, the die can be used as set to finish off the mandrel nose thread. By doing this, you can be sure that any accessory produced later on for fitting on the mandrel nose will be a nice fit if it has a tapped thread in it.

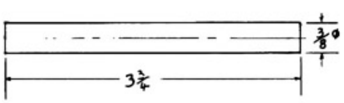
So with the lathe set up for screwcutting 16 t.p.i., the mandrel can be finished off by providing it with its threads. Note that this is NOT done between centres. Thread the tail end first. Grip the nose end in the three-jaw chuck, with the nose itself and the collar inside the body of the chuck and the tail end supported on the back centre. Use a tailstock dieholder if you have one big enough to take the ½ in. die when it comes to finishing the thread. When the tail end is done, reverse the mandrel in the chuck and slide as much as possible of the tail end into the chuck, so that the mandrel is not gripped on the newly completed thread. If the lathe has a mandrel bore big enough to accept the mandrel nearly up to the nose collar, so much the better. If much has to protrude, use the tail centre again for support. Screwcutting drill as for the tail end, chasing up with the die. When the nose is finished—

BACK GEAR BRACKETS

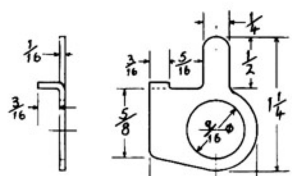




BACK GEAR BUSHES

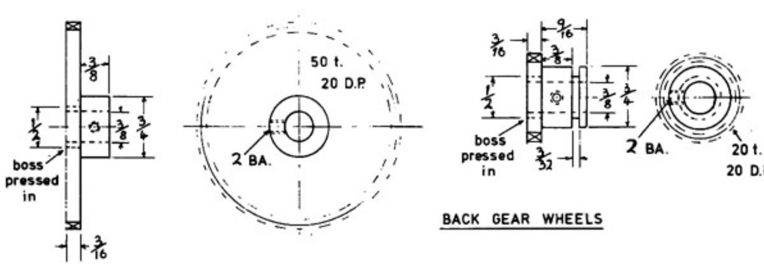


BACK GEAR SHAFT



LOCKING LATCH

check on job



BACK GEAR WHEELS

and you can try the fit of the nuts on it—restore whatever train of change wheels you normally keep set up, if like me you leave a "self-act" train more or less permanently in place.

Plain lathe builders can now move straight on to the pulley, as that is all they will require to complete the mandrel assembly. Pulley sizes for the plain lathe can be somewhat larger than those specified for the back gear model if preferred, as the size of those used with back gear is limited by the amount of room available between mandrel and back gear shaft. Having more room there on the plain lathe means that the pulleys could be made big enough to accept a larger belt, a flat belt, or even "M" size endless V-belts—⅜ in. across the flat top. The decision as to whether to take advantage of the extra space and if so, in what way, can safely be left to individual builders.

So we come to considerations of the back gear mechanism itself. The items to be tackled first are the two brackets carrying the back gear shaft. These, as has already been mentioned, are held in place by the threaded extension of the rivets for the bearing adjuster pads and the top bed bolts through the headstock columns. First we need a couple of packing pieces to go on the top studs to bring the brackets vertical, as the brackets at the bottom are bearing on the outside of the bed side plates. The packing pieces are merely rectangles of 1 x ¼ in. strip, drilled ⅜ in. to fit over the collars of the rivets at the back.

The brackets themselves are shaped up from 1½ x 1½ x 3/16 in. bright mild steel angle. Cut them a trifle full on length, roughly square the ends and cut down one side to 1 in. wide to match the width of the headstock columns. Note that as soon as you have done this they become "handed", and as they are not the same from now on, it is as well to make sure that what you are doing is being done to the right one! The first operation on both is to drill for the top stud hole, checking from both the job and the drawing that you have a little spare length top and bottom. With the hole drilled, remove the top headstock bolt and clamp the bracket temporarily in place on the top stud and adjust it to stand truly vertically, as shown by a try square stood on the same true surface as the lathe. With it correctly positioned, clamp it additionally to the bed at the bottom and spot through the bed bolt hole for drilling for the bottom bolt hole. Drill the hole in each, squaring off both to the same length below the bottom hole.

For the next stage—locating the back shaft centres—we need two of the four gears that will be used for the back gear. It is almost certain that the gears you obtain commercially will need modifying as to their bores. The whole lot of them will need treating the same, but it will be sufficient now just to deal with one pair so as to be able to complete the back gear.

The modifications required to the gears consist of removing any bosses fitted, and to open up the small bore to ½ in. diameter so that the gear finishes up as 3/16 in. thick toothed disc bored ½ in. If you use Bond's gears like the ones shown, the different size gears have to be treated differently. With this series, gears up to 35 t. are in one with their boss, while sizes larger than this have a separate boss pressed in. For the brackets job in hand at the moment, we need a 20 and 50 t. pair. This means that the 20 t. gear can be chucked by its boss and bored out straight away to ½ in. diameter, a snug fit on the mandrel. Face off flush the thin shell of boss left after boring out. With the 50 t. one, the boss should be pressed out in the vice. On the end of a short stub of ⅜ in. diameter steel rod turn down a short length to ¼ in. diameter to fit the bore of the gear. Pop this into the wheel opposite the boss and slip a collar of tubing or a large ball race outer ring over the boss, and squeeze the pressed-in boss out in the vice. The size of the hole left in the gear wheel could vary; if it is a smooth ½ in. you are home and dry. If it is larger, turn up a temporary sleeve to fit snugly inside, bored ½ in. like the smaller gear. The back gears running together are two pairs of 20 and 50 t., so slip the mandrel into place in its bearings, threading on a 50 t. wheel between the bearings as it goes in. One more

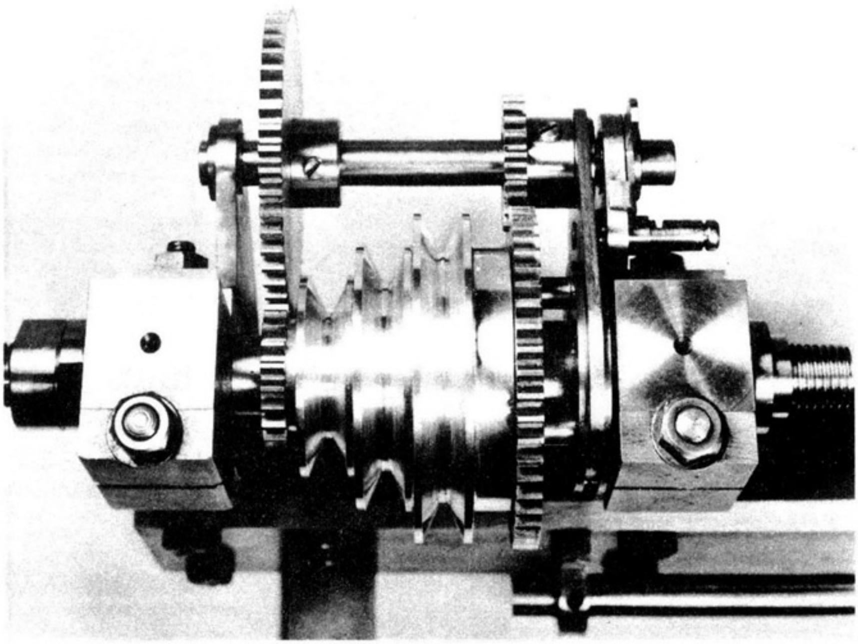


Fig. 19. Back gear engaged; gears in mesh and driving pins withdrawn from pulley.

temporary little gadget is required. and that is a stub of $\frac{1}{2}$ in. diameter rod, $\frac{1}{2}$ in. or so long, drilled centrally through $\frac{1}{4}$ in. Cut a 1 in. or so length of $\frac{1}{4}$ in. silver steel rod and turn one end to a point like a centre punch. Harden it right out.

Slide the 50 t. gear wheel along the mandrel till it is against one bearing bush, then mesh the 20 t. wheel with it, running a narrow strip of thin paper between the teeth to provide positive clearance. Pop the pointed rod in its $\frac{1}{2}$ in. collar through the bore of the 20 t. wheel, when it can be used as a scriber, pressing the two wheels together so that the scribing point can be swung in an arc round the 50 t. wheel and the mandrel centre. Scribe a short arc on the inside face of the bracket attached to the headstock column next the big wheel. Slide the 50 t. wheel up to the other column. turn the 20 t. wheel round to point the other way. and scribe a similar arc on the other bracket.

To fix the exact points for the back shaft centres, pull out the mandrel and the 50 t. wheel, and in one bearing push in the scriber and collar used in the 20 t. wheel. Locate the scriber point pointing inwards. Stand the lathe on a true surface and set the scriber point of a surface gauge to the point of the scriber in the bearing. Scribe a line at this height on the bracket crossing the arc made by the gear wheels, and the cross-over point will be the right distance away from the mandrel for the gears to mesh nicely, and at the right height in relation to the mandrel. Repeat for the second bracket; the photograph, Fig 18, shows this being carried out.

Cente dot the point so found on each bracket and from these dots, circles, arcs and lines can be marked in for shaping the brackets. Note that they are not exactly similar as the R.H. bracket is also concerned with the back gear selection components.

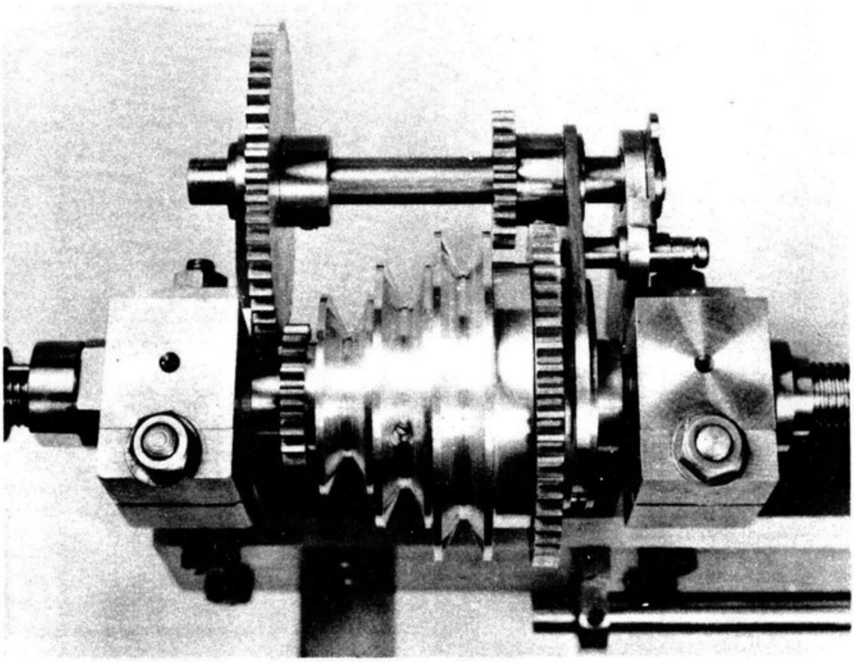


Fig. 20. Direct drive position; back gears out of action and driving pins locking pulley and bull wheel together.

Perhaps here would be a good point at which to explain just how the back gear is operated, and the pair of photographs showing it in each of its two possible positions should help make things clear.

A 20 and 50 t. gear wheel are both fixed on the back shaft, which is free to slide sideways a short distance in its bearings in the brackets. Meshing with these is a similar pair on the mandrel. The small 20 t. gear on the mandrel is not attached to the mandrel in any way, but is permanently fixed to the end of the cone pulley. The large 50 t. gear on the mandrel is at the other end of the pulley, next to it, but free of the pulley and fixed to the mandrel. The two gears on the back shaft and the large mandrel gear are mounted on collars for fixing via grub screws to their shafts. As the flat face of the large mandrel gear—generally called the "bull wheel"—runs against the flat face of the pulley, the bull wheel collar comes between the gear wheel and the R.H. mandrel bearing. Surrounding this collar and riding on it is a turned ring, free to slide sideways on the bull wheel collar. This ring has three short but stiff pins pressed into it, pointing towards the pulley; they pass through three corresponding holes in the bull wheel. When the ring is at its furthest point to the right, the pins do not reach the pulley, which is thus free of any connection with the bull wheel. The pulley is always free to run loose on the mandrel and is at no time fixed directly to it. When the ring is slid to the left, the pins project through the bull wheel and engage three holes in the face of the pulley, locking pulley and bull wheel together so that they revolve as one.

The ring carrying the three pins has a $\frac{3}{32}$ in. wide groove turned in its outer edge, and there is a similar groove turned in the collar of the small gear wheel on the back shaft meshing with the bull wheel. Engaging both these grooves is a

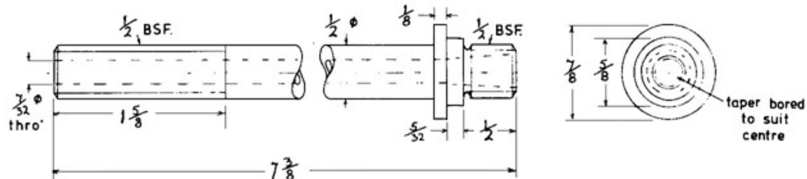
double-ended selector fork piece, like that in a car gearbox. When the selector is slid to the left it moves the ring towards the pulley, when a slight movement of the free pulley enables the pins to pick up the holes in the pulley face and the ring to complete the sideways travel to engage the pins fully with the pulley. This same side movement has also moved the back shaft and its gears sideways, throwing the two back gears out of mesh with those on the mandrel. This is direct mandrel drive position, where the back shaft and gear remain stationary and play no part in the action, while the pulley is locked to the bull wheel and drives the mandrel, the bull wheel being fixed to the mandrel. When the selector is moved the other way to the right, the pins are withdrawn from the pulley leaving that completely free on the mandrel, and the back shaft is slid to the right re-meshing both pairs of gears. This is the back gear engaged position, and the drive is then via the small gear attached to the pulley, which drives the back shaft through its mating 50 t. gear. The back shaft thus now being driven, the small gear on the back shaft drives the bull wheel on the mandrel at a reduced speed, the pulley running much faster on the mandrel. As two 20 : 50 pairs of gears are involved, the geared-down ratio is $6\frac{1}{4}$: 1.

The selector fork plate is prevented from flopping about by being mounted on a short pin sliding in a bush in the R.H. bracket, and a small latch swinging about the R.H. back shaft bearing bush can engage a notch on this pin, serving to lock the gears in either selected position. The sliding back shaft is quite conventional, but the method of operating it with the selector fork is rather different to that normally employed. Most commercially produced lathes require the use of a spanner or other key to change from direct drive to back gear or vice versa, while the system used here is much quicker and needs no separate tools.

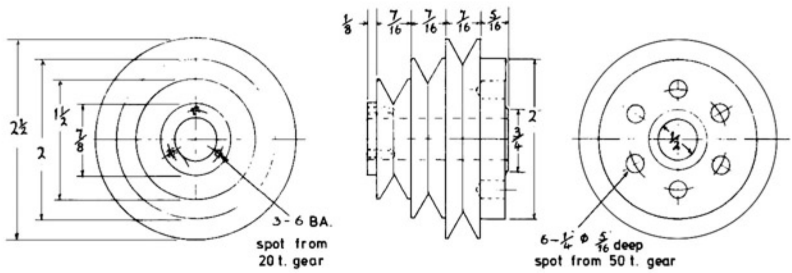
The most convenient order in which to make the various items is to complete the back shaft assembly first, so the next things could be the bearing bushes for the back shaft. These, like the mandrel bearings, can be of whatever bearing metal you happen to prefer. Both are bored a snug fit for the $\frac{3}{8}$ in. diameter shaft, which is just a straight length of ground rod. The bush for the L.H. bracket can be pressed straight in when made (or Loctited), but it is useful to provide the R.H. one with a very slight tapered "lead" to the end, so that it can be stuck into place in the bracket finger tight for trying various fits, before pressing it permanently home. The R.H. bush differs from its opposite number in that it has a double diameter under the flange, the larger one being the pivot for the back gear selector locking latch. Find a scrap of $\frac{1}{16}$ in. steel plate suitable for the latch and drill or bore a clean $\frac{9}{16}$ in. hole in it, then this can be used as a gauge in making the bush—not only for the diameter under the flange, but also for the depth of it.

With the brackets, bushes and shaft complete, the next things are the two bosses for the gear wheels going on the shaft. The two wheels with their bores opened up to $\frac{1}{2}$ in. are ready made for this, and the collars are plain turning with a stepped diameter sized for a press fit in the bore of the wheels. Ream the bores of the bosses for a snug fit on the shaft—the gears should run as nearly dead true as you can get them. Here again, they can be pressed into the wheels or Loctited; just for 100 per cent security, I did both! On the point of security, the grub screws securing them to the shaft are 2 B.A., bearing on small flats filed on the shaft. Two screws can be fitted if thought desirable.

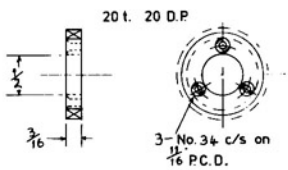
When you come to make the boss for the 20 t. gear on the back shaft, first select the piece of $\frac{3}{32}$ in. plate that you propose to use for the selector plate. Clean up one edge of this straight and true, with no burrs, then not only have you a true edge for marking out the forks, but the piece can be used as a gauge for sizing the width of the groove in the gear wheel boss. The groove is turned in—at a low lathe speed—with a narrow parting tool. Make sure the tool point has keen corners, then you will not get a false fit with the fork binding near the bottom of the groove. That completes

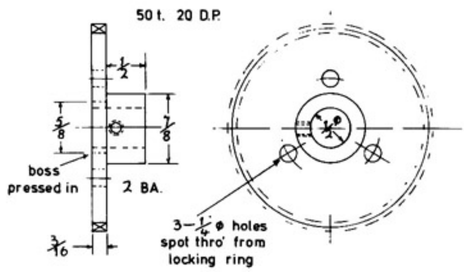


MANDREL

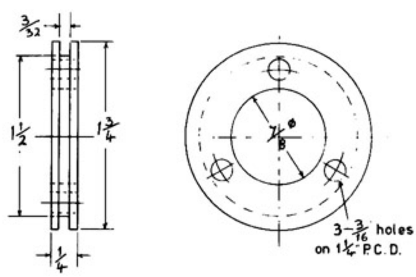


PULLEY Lt. alloy

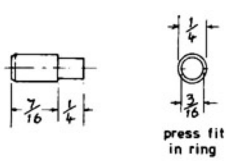




MANDREL GEARS



LOCKING RING



LOCKING PINS
M.S. 3 off

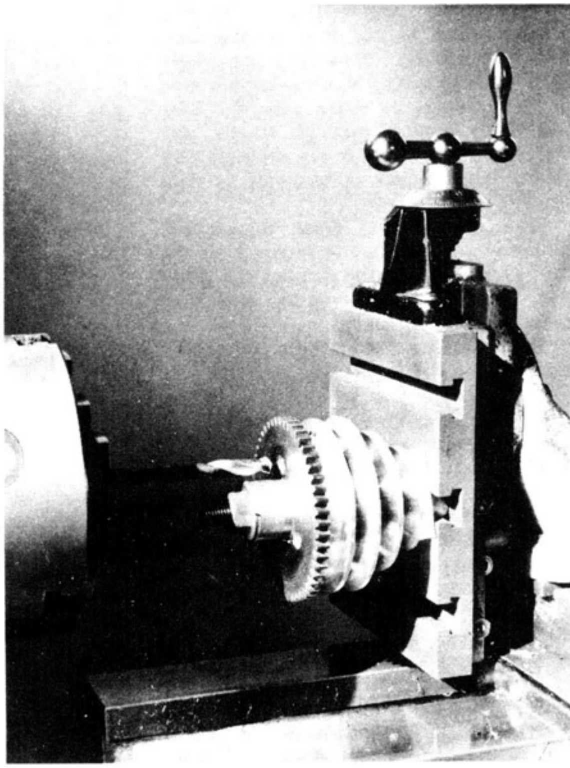


Fig. 21. Jig-drilling the pulley face for the back gear driving pins.

the back section about as far as possible at this stage. About the last job is the latch, which means that the R.H. bush cannot be fitted for keeps till the latch is finally shaped, as the latch is retained in position by the bush flange.

So now it is back to the mandrel for the items mounted on that. The first of these could well be the pulley. This is turned from a chunk of $2\frac{1}{2}$ in. diameter light alloy rod, and is a commercial item. Obtain a piece 2 in. long; this is slightly longer than the finished pulley will be, but it gives you a chucking piece on one end that is useful in machining the belt grooves. Before starting the machining, it is worth while making a form tool for the grooves. If you shape this up from a short length of $\frac{5}{16}$ in. square silver steel, forming cutting edges both sides, it will be narrow enough to permit a slight sideways movement while turning so as to be able to skim one side of the groove at a time, and will also enable the tool to get at the side of a groove right next the larger diameter of a groove alongside.

Chuck the piece in the three-jaw and take a light skim over as much of the outside as you can reach, and lightly face up the outer end. Start by reducing the diameter in three steps for the three groove sizes; this will give you a good idea of where to start turning each groove, as the middle of each groove can well be judged by eye at this stage. Note that there is a $\frac{1}{8}$ in. deep plain diameter smaller than the grooves at the extreme end. Complete each groove with smooth sides at a low turning speed when the "blank" diameters are correct and to the right width. With all three finished, without disturbing the piece in the chuck, start in to machine the bore. I drilled through first with $\frac{1}{4}$ in. drill, following

up at a slower speed with $\frac{7}{16}$ in., keeping a close watch to see that the drill continued to run true. Then followed a light skim through with a slim boring bar held in the toolpost to make sure the bore was really true all through, finally sizing with a $\frac{1}{2}$ in. reamer run through very slowly with several withdrawals to clear the fine swarf.

With the grooves finish turned, the pulley is not too easy to re-chuck by the thin groove edges for turning the other end, but the next operation will very much simplify this.

In the bottom of the middle groove drill a No. 34 hole right through into the bore and tap the top $\frac{3}{8}$ in. or so 4 B.A. In use, this serves as a lubricator, as the bore of the pulley needs lubrication when it is running free on the mandrel. A short grub screw closing the tapped hole is removed periodically for the insertion of the oil. However, just now the tapped hole can be provided with a much longer screw—turned down to pass through the untapped bottom of the hole—by which the pulley can be locked on a short piece of $\frac{1}{2}$ in. diameter rod held in the chuck; in other words, an arbor. Mount the pulley this way, with the small end next the chuck, and finish turn the large outer end to the sizes shown. Take light cuts, as this set-up represents a fair overhang on the job. In facing the large outer end, take the greater part of the face a few thousandths further back than an area about $\frac{3}{4}$ in. diameter in the middle. This will leave a ring about $\frac{1}{8}$ in. wide to run against the bull wheel, reducing friction and any tendency of the pulley to cling to the face of the bull wheel with oil.

The next item to take in hand is the bull wheel—one of the other 50 t. wheels. Press out the boss as before and chuck the wheel gently over the teeth so that it runs quite true, and bore out the hole left by the boss to $\frac{3}{4}$ in. diameter. Turn up a new boss, $\frac{7}{8}$ in. diameter and bored $\frac{1}{2}$ in., turning the step where it goes into the wheel to a press fit. Drill and tap it for a 2 B.A. grub screw (or for two screws, if you prefer), locating the tapped hole as close as reasonably possible to the face of the gear wheel. The screw cannot be in the middle of the length of the boss, as the sliding locking ring will cover this position and it will be found impossible to get at the grub screw when it comes to assembly. As the ring slides over the screw, this must obviously be short enough for its end to come just below the surface of the boss. Press the new boss firmly and squarely into the wheel, and that is that.

With the bull wheel complete, the locking ring can be made to fit it, turned from an odd piece of the $\frac{1}{4}$ in. plate. Saw a piece roughly round, drill a $\frac{3}{8}$ in. hole through the middle, and with the piece mounted on a short $\frac{3}{8}$ in. bolt held in the chuck, turn the outside to size and run in the groove for the selector fork, using the piece of $\frac{3}{32}$ in. plate as a gauge again. When the outer rim is finished, re-chuck the ring by the edge and bore out the central $\frac{3}{8}$ in. hole an easy sliding fit over the bull wheel boss. Before removing it from the chuck, divide round the face for three positions accurately spaced for the locking pins. The easiest way to do this is to stand a piece of bar or rod with flat ends upright on the saddle so that the nearest jaw of the three-jaw chuck will contact the top, using it like a stop. A piece $2\frac{3}{4}$ in. long is needed for the ML7. If a true-edged piece of square bar —such as a lathe tool blank—is gripped in the toolpost so that it lays across the face of the ring at centre height, just clearing it, this can be used to scribe against, marking three lines across the face of the ring. Odd leg dividers can then be used to mark in the three crossover points for the centres of the holes for the pins. Centre dot these three points accurately and drill them $\frac{3}{16}$ in.

The holes in the ring need to be transferred to the bull wheel, so clamp the ring against the wheel over the boss and spot through the three holes on to the wheel deeply enough to be sure that the drill has a positive start. Remove the ring and drill the three holes through the wheel $\frac{1}{4}$ in. diameter. The pins themselves could next be made, turning them from a stub of $\frac{1}{4}$ in. rod. Make the $\frac{3}{16}$ in. diameter ends a tightish press fit in the ring, and very lightly chamfer the outer $\frac{1}{4}$ in. ends to give them every assistance to enter the holes in the pulley smoothly.

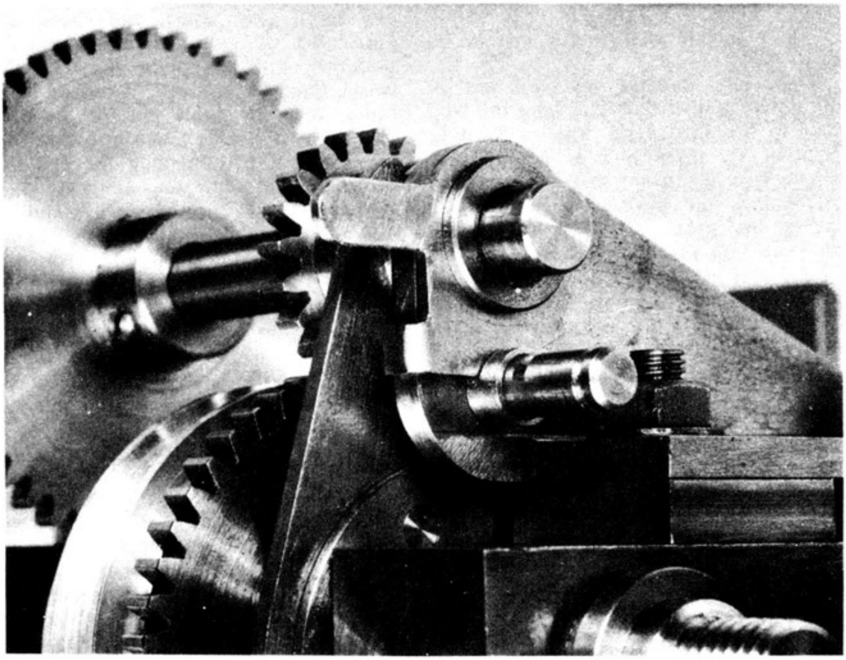


Fig. 22. The back gear locking latch.

Press them squarely home into the ring. You can now check that the ring when placed over the bull wheel boss will slide the pins smoothly into the holes in the wheel. They should do this in any of the three possible positions, but you may find one position which they do not seem to like very much. By trying gently to rock the ring with the pins in their tightest position you can feel which one or two may be rubbing in the hole, and the appropriate hole can be gently eased a fraction with a dead smooth round file.

There is still one more matching set of holes required, and this is in the face of the pulley. The photograph, Fig. 21, shows the set-up I adopted for this, which ensures a truly square and accurate result. Firstly, the bull wheel must be held precisely in line with the pulley, and the easiest way to bring this about is to drill a short piece of $\frac{1}{2}$ in. rod axially through the centre to slip over the size bolts or studs you use on the vertical slide—in this case $\frac{5}{16}$ in. This piece is slipped half into the bore of the pulley and the bull wheel popped over the outer end. A single stout bolt or stud through the lot then holds everything secure, and each hole in the gear wheel can be exactly lined up with the drill by movements of the cross and vertical slides. Drill all three without moving the job on the vertical slide. When all three have been taken in to depth, slack off the clamp nut and turn the bull wheel $\frac{1}{6}$ of a turn in relation to the pulley, so providing two alternative sets of holes for the pins. This cuts out some fiddling when engaging back gear, as the pulley only has to be moved a fraction of a turn for a set of holes to line up with the pins.

With the six holes drilled, once again the fit of the pins themselves can be checked in every position, only this time the pulley and bull wheel can be threaded on the actual mandrel. If any one or more are tight or reluctant, treat the offending hole or holes in the pulley with a very gentle scrape with the end of a

reamer held in the fingers. The pulley material is soft enough for this to be easily done.

There now remains one more job on the pulley, and that is attaching the 20 t. gear to the small end. This is fixed in position by three 6 B.A. countersunk screws tapped into the end of the pulley. So modify the gear wheel as before, taking the bore out to a snug ½ in. diameter and turning away any remains of the boss. At the end of the boring out operation divide round for three positions as was done for the locking ring, mark in the three drilling points, centre dot and drill through No. 43. Here again a stub of ½ in. rod can be used to line them up, slipped through both pulley and gear wheel, and with this in position clamp the two together and spot through the gear wheel for the three hole positions on the end of the pulley. Separate, drill the three positions quite squarely about ⅛ in. deep and tap 6 B.A. Open up the holes in the gear to No. 34, countersink one side, and check that the screw heads do not just foul the bore of the wheel. Mine just did by a few thousandths, so I chucked each one gently and took just the lightest skim off the sharp edge of the head. They should screw home flush with the face of the gear. Try the wheel in each of the three possible positions for true running when the pulley is spun on the mandrel: if there is any difference, adopt the truest running position as the "proper" one. When you are satisfied with the way it all goes together, the next move is on to the selector fork plate.

If this is marked out according to the drawings on the $\frac{3}{32}$ in. plate, the two horseshoe shapes engaging the ring and back gear boss can be bored in the four-jaw chuck or on the faceplate. It helps in boring the big one if the plate is left long enough to accommodate a complete hole, then the surplus can be cut away when shaping up the plate. The holes can be takén out to quite a slack fit over the bottom of the grooves, which could help cancel out any slight inaccuracy that may have crept in as to hole spacing. When the plate is shaped up, roughly assemble mandrel, bull wheel, ring, back gear shaft and small gear wheel, and check that everything is quite free to revolve smoothly with the plate "floating" between the two grooves. When all is in order, then the guide pin for the plate and its bush can be taken in hand. Turn up the bush first, making the end that protrudes through the bracket small enough to slide through easily, and the half nearest the small flange slightly larger so that it will be a light press fit in the hole in the bracket. The bush can be machined up from a stub of mild steel rod as it has no revolving shaft in it and comes in for very little real use. Leave filing the latch slots in it for the time being, and press it home in the bracket.

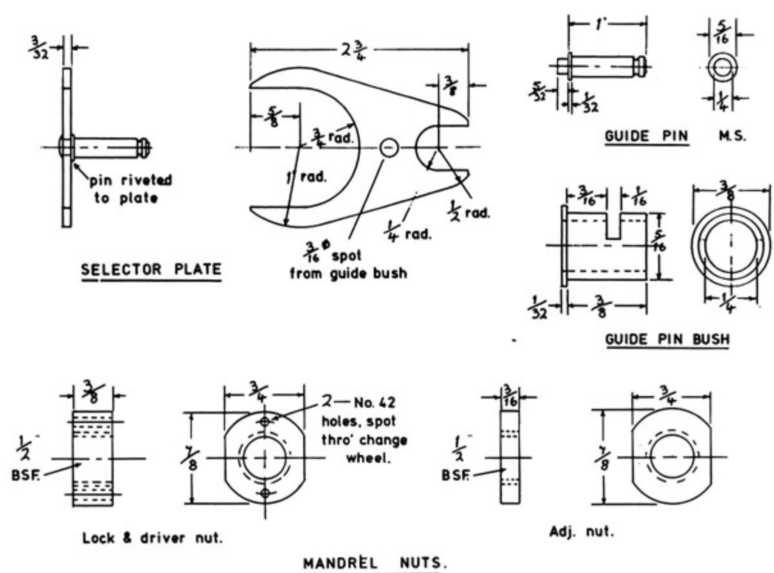
With the selector fork in position about the two grooved members that it has to move, slide it as far as it will go to the right, close up to the headstock column, and mark on it the drilling position for attaching the guide pin. It can be marked clearly enough by turning a drill through the bush with the fingers and pressing the point against the plate. Strip down again, remove the plate, centre dot the faint mark from the drill point and drill through $\frac{3}{16}$ in. De-burr the hole both sides. Turn up the pin a close fit in the bush and rivet it in place on the plate.

The length of mandrel between the inner ends of the headstock bushes should be something like ¼ in. greater than the total length of pulley and bull wheel. This space is taken up by a short spacer between the small gear wheel on the end of the pulley and the L.H. mandrel bearing bush. With the several components threaded on the mandrel it is very easy to build up a small difference in dimensions overall, so that the spacer length cannot be positively dimensioned. Indeed, the provision of the spacer allows for this to be taken care of, and so the spacer is sized to fit snugly in the space left for it. Make its length such that there is just the slightest perceptible end play on the pulley when all is assembled —including the locknuts adjusting the mandrel end play.

The latch is sawn and filed to shape from the scrap of $\frac{1}{16}$ in. plate which had the $\frac{9}{16}$ in. hole drilled in it. In completing

the shape, leave it full wide, so that the edge which will enter the slot in the guide bush needs to be taken back a trifle before the latch can engage. I found it best, to make sure of things, to knock up a dummy back shaft bush with the same diameters as the proper one, but making all the diameters free in the various holes. It can be roughly drilled $\frac{1}{8}$ in. to accept the end of the back shaft. File the notch in the bush, making one side of it come flush with the outer face of the bracket. Its width can be gauged with the latch itself. Pop the dummy bush through the latch and into the hole in the bracket, when you can quickly see how much the "leading edge" of the latch needs adjusting to let it engage the slot cleanly. Bend over the top tab of the latch to act as a stop before doing the final adjusting. When it works smoothly, transfer the latch to the proper bush and press this home in its hole in the bracket.

Re-assemble all the completed bits and carry out the final "timing" operation. This consists of adjusting the position of the gears on the back shaft so that they are fully engaged with the gears on the mandrel when the lock pins are fully withdrawn, and so that they come in the middle of the free space for them when the pins are pushed right home. This gives you the extent of the travel of the guide pin through the bush, and this is marked on the pin with a small knife-edge file through the slot in the guide bush. Strip out the selector plate and file the two notches in the pin marked through the slot in the bush in both positions. Check that all works smoothly and that the latch engages easily in both positions of the selector plate, and that completes the work on the back gear.



CHAPTER SIX

Screwcutting Gear

THERE now remains only the few straightforward components needed for the screwcutting feature to complete the whole job.

About the most convenient point at which to start to make these is with the change wheel banjo. This is shaped up from the familiar 2 x $\frac{1}{4}$ in. steel strip, and it is advisable to mark this out fully and clearly before cutting into the piece. To get the various arcs correctly sized and positioned, the surface on which the dividers are centred should be level with the piece being marked out, and I arranged this by using an odd piece of the $\frac{1}{4}$ in. plate positioned alongside the work piece so that it covered the area on which the various centres come. Settle it close against the true edge of the work piece and clip it in position with a couple of small toolmakers' clamps. Marking out is quite simple, being all circles and arcs.

When you have everything necessary marked on, detach the side piece containing the centres and roughly saw out the banjo to shape. The bottom $\frac{3}{4}$ in. diameter hole needs to be smoothly finished to accept a bush pressed in, so it is best to bore this out rather than just drill it—even if you do have a $\frac{3}{4}$ in. drill! Before you start to bore out this hole, drill a series of holes—about $\frac{7}{32}$ in. diameter—along the line of the curved slot and roughly file out the slot nearly to size. Then you can use a couple of small bolts through the slot to attach the piece to the faceplate for boring the bottom hole. You can comfortably swing this length in the gap of a $3\frac{1}{2}$ in. lathe.

Incidentally, the curved shape of the slot and the banjo itself is not just to make it look pretty. It would be easier to shape if it were just a straight arm with a straight slot. The sides could then be end milled or fly-cut, and the slot end milled complete at the one set-up. However, on trying out a variety of straight shapes on paper, it was found that sufficient length of slot could not be accommodated in a straight banjo to accept all the possible combinations of change wheels for the finer threads. Furthermore, when the longest possible straight slot was fully occupied with a change-wheel train, the top driven one came too high above the mandrel centre line for the top end of the banjo to get close enough to let the top wheel engage with a 20 t. mandrel driving wheel. Even using a double slot banjo with the slots parallel or fanned apart, as is done on some lathes, it was still not possible to set up every train that might be required. So the curved banjo was resorted to, the curved slot providing just that little extra length that makes all the difference, and allowing the top end of the banjo to be brought close enough to the mandrel collar. So there we are—curved it had to be!

With the bottom hole finished bored, drill and tap the hole alongside it for the locking screw, file the slot to a smooth finish so that the shank of a $\frac{1}{4}$ in. drill can slide freely from end to end, and finish file to shape on the outer edges. A nice finish should be aimed for on this piece, as it is a very conspicuous part of the lathe.

The bearing plate mounting the banjo on the end of the bed should be the next piece to take in hand, as when the $\frac{3}{4}$ in. hole is finished in that we have the two holes which can be used as gauges for sizing the bush in the banjo. Like the banjo, the hole can be bored on the faceplate or in the four-jaw chuck, and the short slot produced from filing from a line of holes. This is also from 2 in. wide strip, and in fact I made the one shown from the odd piece that was used to mark out the banjo. It can be attached to the end of the bed in two or three different ways; you can use three 4 B.A. screws as was done with the lead screw bearing plate at the other end, or use fewer 2 B.A. screws, which means tapping fewer blind holes in the bed mem-

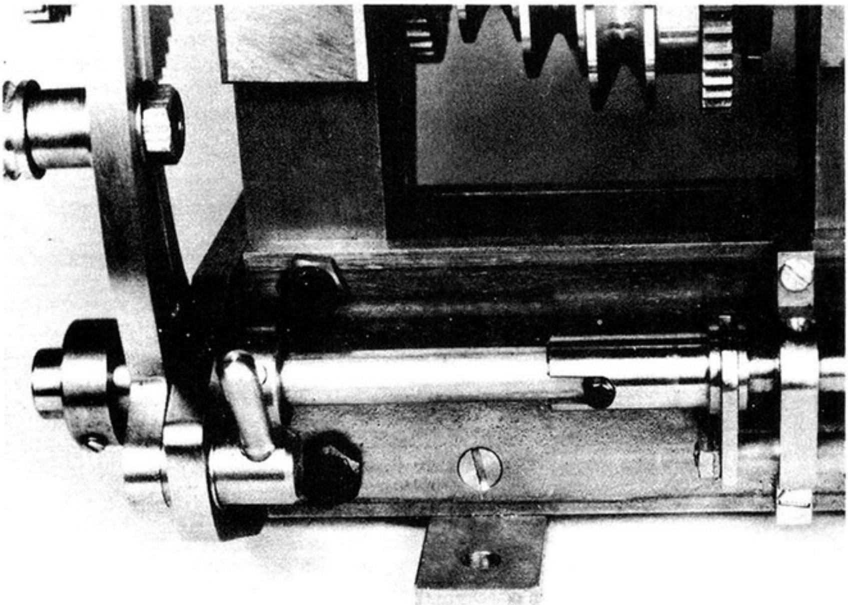
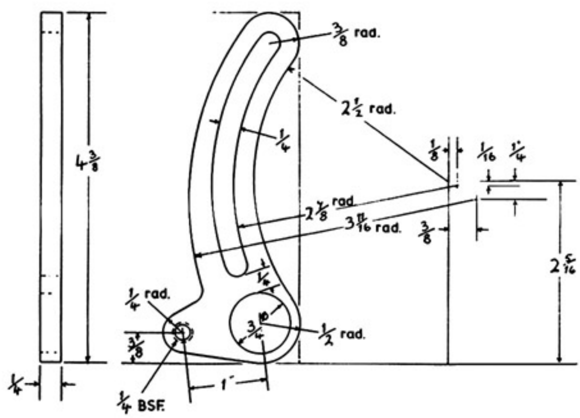


Fig. 23. Lead screw drive shaft, showing clutch and banjo position lock.



CHANGE WHEEL BANJO.

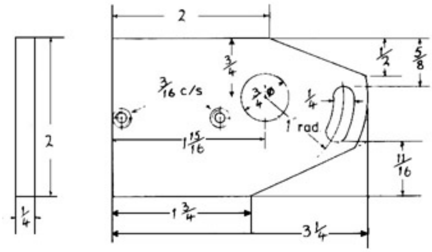
bers. Thinking that on the whole it might be subject to fewer "wringing" strains than the bearing plate by the lead screw handle, I chose to mount it by two 2 B.A. screws. Note that whatever screws are used, it is preferable to tap these into the ends of the bed side plates rather than into the headstock column. If you choose to use three 4 B.A. screws, locate one halfway up the width of the plate at the back. The bottom nearest one can go right in the bottom corner, as the bottom ¼ in. bolt has been raised in its position through the headstock column to allow room for it to pass underneath. The top screw in the same plate edge could come below the bolt. A pair of 2 B.A. screws can go in the middle of the width of the plates as shown. As a 2 B.A. screw in the back position comes near enough to the back edge of the bearing plate to begin to overhang the edge, I skimmed the head a shade smaller for neatness. Leave drilling for the fixing screws for the time being, as when the short lead screw drive shaft is made and fitted, it can be assembled in the bush and used for lining up to get the bearing plate correctly positioned.

The bush that we are now in a position to turn up is from a short length of 1 in. steel rod. While its two smaller diameters are both shown as ¾ in., the one which goes in the hole in the banjo is made a press fit, while the other is a snug moving fit in the bearing plate. Chuck the rod and turn the side first that goes in the bearing plate; this should be nicely concentric with the bore, and this can be ensured by doing both at the one setting. Concentricity of the other side—the press fit side—with the bore is not quite so important, so holding it in the three-jaw by the side first turned will be good enough—provided the chuck is not wildly inaccurate. The bore should be a smooth ½ in. diameter for a bearing bush for the drive shaft.

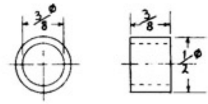
In case it has not been mentioned before, in all cases where a press fit is specified a stiff "finger press" fit assembled with Loctite should be equally satisfactory. If you prefer to adopt the cautious "belt-and-braces" technique, a light press fit assembled with Loctite should make doubly sure. Make sure you press the bush into the right side of the banjo! With the banjo laying flat as shown in the drawing, the bush goes in from the upper surface. Into the banjo bush which pivots in the bearing plate goes the drive shaft bearing bush and, like all the others, this can be of bronze or cast iron. Here again, light press fit or Loctite.

The banjo is held in the required position by a short bolt operated by a finger lever, and this is a few minutes' job from a stub of ½ in. round steel rod. Provide a small washer for it of the same thickness as the central flange on the bush; this goes on the locking bolt between the banjo and the bearing plate, so that the banjo is not strained sideways when the bolt is tightened. Assemble the banjo in the plate, run in the bolt and tighten it gently with pliers. Mark the top of the head when it is tight so that a finger lever tapped into the head at the marked point comes vertical when the banjo is locked. Swinging the lever a third of a turn or so forwards frees the banjo for repositioning. Turn up the lever from a piece of ¼ in. rod and assemble in the lever. This is screwed into the bolt by its 2 B.A. threaded end; do NOT use Loctite here, as it may need to come out from time to time to remove the banjo, as there is not room to swing the lever right round and clear the side of the bed.

The purpose of the short shaft running in the banjo bush is to transmit the drive of the last gear wheel in the train of gears to the lead screw. The main length of the shaft is ⅜ in. diameter to match the end of the lead screw, while the short outer end is ½ in. diameter to accept any gear wheel. Connecting the ends of shaft and lead screw is a sliding sleeve—a free running fit on both. The sleeve contains a plug, pinned in position, shaped at the end next the lead screw like a D-bit or halved joint. The end of the lead screw is similarly shaped, so that when the sleeve is slid towards the lead screw the shaped plug can engage the end of the lead screw in one position only and one can drive the other. By sliding the sleeve towards the banjo, the dog clutch—for that is what it is—is dis-

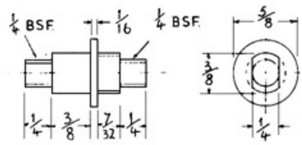


BANJO BEARING PLATE

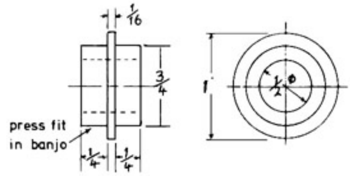


CHANGE WHEEL BUSH

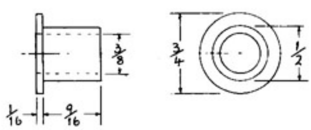
bronze 2 off



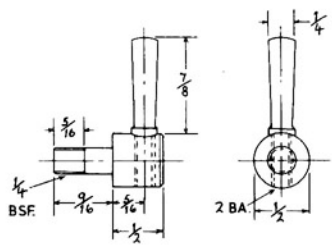
CHANGE WHEEL STUD 2 off



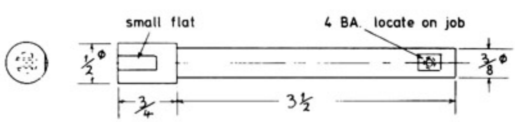
BANJO BOSS



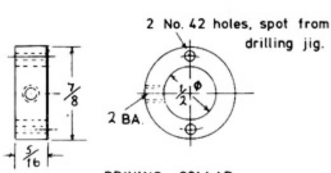
BANJO BUSH C.I. or bronze



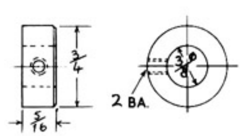
BANJO LOCK SCREW



CLUTCH SHAFT.



DRIVING COLLAR



CLUTCH SHAFT COLLAR.

engaged, and the gears and shaft are free to revolve without moving the lead screw.

So the next compartment is the clutch shaft itself, from which we can locate and fix the bearing plate to the end of the bed. The shaft is plain turning from a length of $\frac{1}{2}$ in. diameter rod. If you want to make sure of a true shaft with the minimum of turning, the easiest procedure is to cut a piece $\frac{3}{8}$ in. true rod to length and Loctite a $\frac{1}{2}$ in. diameter sleeve on the outer end. Both can be left very slightly overlong, when facing the $\frac{1}{2}$ in. diameter end will leave a finish indistinguishable from a solid shaft. This was done in the case of the shaft shown, and it shows every sign of being perfectly satisfactory. Make the $\frac{3}{8}$ in. diameter portion of the shaft about $3\frac{7}{8}$ in. long for a start, so that when in position it just clears the end of the lead screw. It will have to be shortened later on to make room for the clutch plug in the sleeve, but the full length just now helps in lining up.

With the shaft more or less complete, leave it with the banjo for the moment while the sleeve is taken in hand. This is plain turning and drilling from a piece of $\frac{5}{8}$ in. diameter rod. In use, the sleeve is moved by a small fork much like that for the back gear, the fork being from a scrap of the $\frac{3}{32}$ in. plate used for the back gear fork. So if you retrieve a small piece of that for the fork, it can be used first as a gauge for the width of the groove in the sleeve. Make the groove width a fairly free fit for the fork material, and run it deep enough for it to be a free fit in a $\frac{1}{2}$ in. hole. Leave the driving slot in the sleeve for the moment.

Assemble the banjo complete to the bearing plate, slide the shaft through the bush into position and thread the sleeve on to the shaft. Offer up the bearing

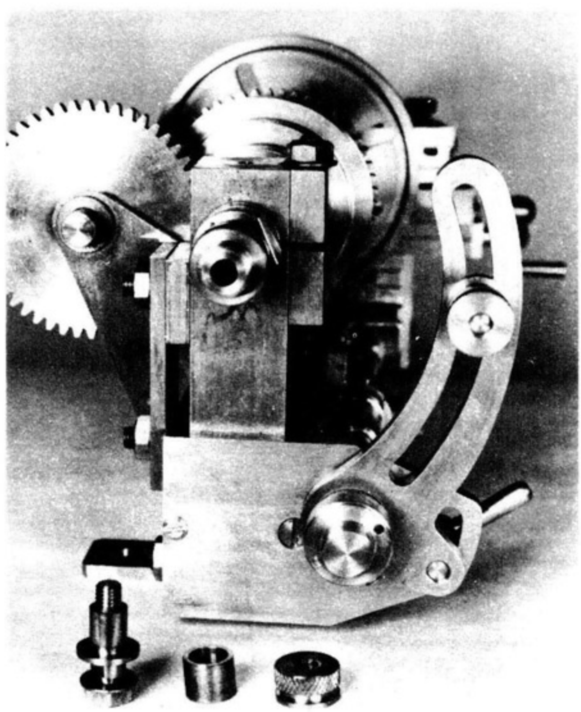


Fig. 24. Change wheel banjo assembled on its bearing plate, with one change wheel stud disassembled.

plate to the end of the bed and make a rough check that things look like lining up. Position the bearing plate level with the top edges of the bed side plates and check by feel that the shaft end and lead screw line up. Clamp the plate in position against the headstock column. Slide the sleeve along so that it goes over the end of the lead screw, and check that the sleeve, shaft and lead screw are all perfectly free to turn smoothly when the sleeve is in position on both. When everything is nicely square, level and lined up, mark on the bearing plate where the fixing screws need to come. If you use 2 B.A. fixing screws there is not a lot of leeway for errors with $\frac{3}{16}$ in. screws in $\frac{1}{4}$ in. thick plate, so make sure you have the positions exactly right. Remove the plate, spot and drill 2 B.A. tapping size. Replace the plate with all the bits attached, check the line-up again, and spot through the screw holes on to the ends of the bed plates. Drill and tap, open up the tapping size holes in the bearing plate to 2 B.A. clear, and countersink on the outside.

To retain the shaft in position, it is fitted with a collar on the $\frac{3}{8}$ in. diameter portion, bearing against the end of the bush. It would be useful to turn this up next from $\frac{3}{4}$ in. rod, fitting it with a 2 B.A. grub screw to lock it on the shaft. The plug carried in the sleeve forming half the dog clutch could be next, sizing the half-thickness end to exactly $\frac{3}{16}$ in. Run the lead screw right out and shape a similar end on that. File a very slight chamfer on the straight edge of the "step" of each piece to help the easy and smooth engagement of the two when the sleeve is slid along.

With the shaft locating collar free on the shaft, slide the shaft along to the left so that the clutch plug can be fitted between the ends of the shaft and the lead screw. Allow a little clearance—$\frac{1}{16}$ in. or so—and measure the amount by which the larger end of the shaft is short of contacting the outer end of the bush; this will be the amount by which the shaft needs to be shortened to accommodate the plug. Mark a point on the plug $\frac{1}{8}$ in. in from the round end—i.e., halfway along the round body part—and drill a $\frac{3}{32}$ in. hole across its diameter for the fixing pin. Hold the plug in position between shaft and lead screw ends with the two steps fully engaged with each other, and the sleeve alongside it with its right-hand end just comortably clear of the side of the lead screw bearing bracket, and mark on the sleeve where the plug pin hole should come when the sleeve position has engaged the clutch. Drill a $\frac{3}{32}$ in. hole through one side of the sleeve. Pop the plug into the sleeve—with the dog end pointing the right way! —and line up the plug pin hole with that in the sleeve. Run the drill back into both holes and complete the drilling through the other side of the sleeve. Countersink both holes in the sleeve quite lightly, insert a short length of $\frac{3}{32}$ in. rod, rivet it over each end and file off flush.

While the sleeve is free to run on the end of the lead screw when the clutch is disengaged, it is driven by the clutch shaft all the time this is revolving. The drive is transmitted with the sleeve in any position by a pin in the shaft riding in a slot in the sleeve. The pin, in fact, is a 4 B.A. socket head cap screw tapped into the shaft, the head engaging the slot in the sleeve filed to fit it. The toughness of the socket head screw material is useful here as compared with mild steel, but we do not really need the knurled surface generally to be found round the heads of these screws. So chuck the screw gently and take a light skim off the outside of the head, till you have a smooth socketed cheese head. A light skim, just enough to produce a smooth surface in my case, reduced the head to a few thousandths smaller than a No. 4 drill. It might pay to aim for a size of head that is a free fit in a hole drilled with the nearest size drill, then a hole so drilled in the sleeve can be an accurate guide as to the width of the slot running into it. Assemble all the bits in position, including the plugged sleeve, and check that the plug location lets the sleeve engage and free cleanly when it is slid either way. If all is in order, slide the sleeve as far as it will go to the left and with a scriber through the drilled hole for the drive screw mark its position on

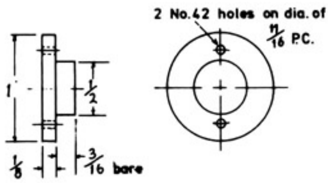
the clutch shaft. Strip out the shaft and centre dotting the screw position fractionally to the left of the marked position, drill and tap the shaft 4 B.A. for the screw. File a small flat on the shaft about the hole so that the screw can bed down flat and secure, and cut the screw down to a length that brings the end just below the surface of the shaft and re-assemble as finished.

The fork actuating the sleeve is a very simple piece, filed up from the piece of $\frac{3}{32}$ in. plate used as a gauge for the groove width in the sleeve. Mark it out and drill the two holes first then file to outline. The fork—and thus the sleeve—is operated by a rod running the length of the bed under the lead screw, using the holes already drilled for it in the lead screw bearing brackets. It is merely a length of $\frac{9}{32}$ in. diameter straight rod. Chuck the rod in the three-jaw, turn down $\frac{1}{4}$ in. or so length to $\frac{3}{16}$ in. diameter and thread it 2 B.A. Slide the rod through its bearing holes from the R.H. end, slip the fork over the sleeve and thread the 2 B.A. end of the rod through the hole in the fork. Run on a 2 B.A. nut and check that the rod and sleeve slide together freely to operate the clutch, and that the sleeve turns freely in all positions when it is embraced by the fork. Slide the rod as far as it will go to the left—in other words, fully disengage the clutch—and mark the rod where it sticks through the bearing bracket at the lead screw handle end. Cut it short at the mark; it will protrude through its bearing some $\frac{3}{16}$ in. or so when the clutch is engaged, but this is of no account as being underneath the boss of the lead screw handle the fingers are unlikely to foul it, and when the clutch is engaged the handle will not be operated by hand anyway.

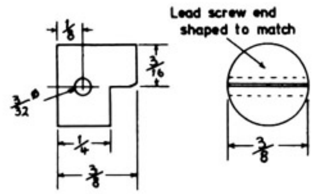
One more little piece remains for what might be called the "permanently installed" part of the screwcutting gear, and that is the small block that rides on the clutch rod and automatically operates the clutch when screwcutting. This is just a small rectangular block, provided with a clamp screw, so that it can be locked on the rod in any selected position. When clamped in position it can be used as an operating knob to work the clutch, so is pushed to the right to engage the clutch at the start of a cut. As the saddle moves along towards the headstock it contacts the block at the pre-set position and carries it along for a short distance. The distance, in fact, is no longer than is necessary to disengage the clutch, when the saddle automatically stops through the lead screw being no longer driven by the change wheels. The tool is then withdrawn slightly, the saddle wound back to the start of the cut again, the tool reset and the clutch re-engaged for the next cut. It is quite a useful fitment, as it does ensure that the cut ends just where it should every time, and the lead screw can only be clutched in at the same angular position of the lead screw every time. It will be appreciated that the clutch cannot be allowed to disconnect the lead screw with any and every pitch of screw. Neither can it with the split clasp nut provided on more elaborate lathes—but that is a matter of turning technique more, and so rather out of the scope of things to be dealt with here.

Making the block involves no more than facing the ends of a piece $\frac{1}{2}$ x $\frac{1}{2}$ in. square steel rod and drilling a couple of holes in it. In tapping the hole for the clamp screw, the hole could well be clearance size for half its depth, saving not only time but wear and tear on the tap; it also serves to start the tap truly in line with the hole. A 4 B.A. clamp screw will provide all the grip necessary and the screw is another plain little turning job needing no detailing. The long rod under the lead screw on which the block rides is provided with a flat about $\frac{5}{32}$ in. wide along that part of the rod where the block is liable to be needed, and this is a plain filing job. On assembly, turn the rod in the fork so that when the clamp screw is tightened the block is horizontal, giving contact depth on the leading edge of the apron plate of some $\frac{1}{8}$ in.

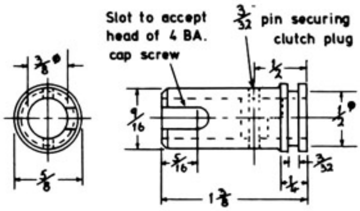
In setting up the change wheels for screwcutting, two small studs will be needed to be mounted on the banjo for the wheels to run on. For some thread pitches the desired ratio can be set up using only one pair of wheels, but you will still generally need the second stud



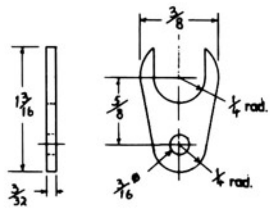
CH. WHEEL DRILLING JIG



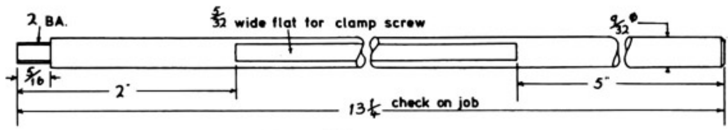
CLUTCH – DRIVING MEMBER



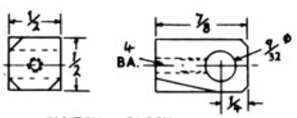
CLUTCH SLEEVE



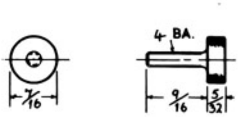
CLUTCH FORK.



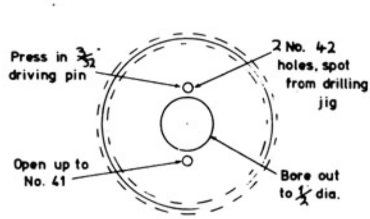
CLUTCH ROD



CLUTCH BLOCK



CLAMP SCREW



CHANGE WHEEL GEARS

to carry an idler wheel to fill up the space between mandrel and lead screw. So make two studs for a start. The easiest way of making these is to turn the plain body part of the studs to $\frac{1}{2}$ in. diameter, so that the wheels run directly on the studs. However, two mild steel items running directly one on the other is not too nice, and a better idea is to make the studs $\frac{3}{8}$ in. diameter and to provide them with floating bronze sleeves, $\frac{1}{2}$ in. diameter, to fit the wheels and $\frac{3}{8}$ in. bore to fit the studs. The sleeves can perfectly well be left to float, the finger nuts retaining the wheels whether the studs are $\frac{1}{2}$ in. diameter or sleeved to $\frac{1}{2}$ in. A $\frac{1}{4}$ in. B.S.F. nut at the back clamps each in position as required at the back of the banjo. The outer wheel retaining nuts can be ordinary nuts if preferred but the knurled finger nuts look somewhat neater and are quicker to whip on and off in use. $\frac{1}{4}$ in. B.S.F. in either case.

The last stage is dealing with the wheels. Bought stock commercial gears will probably be fitted with bosses, bored something like $\frac{1}{4}$ in. The gears shown, which came from Bonds, were of this sort and needed modifying. With these gears, all those up to the 35 t. size have the boss turned in one with the wheel, so the modification with these consists of chucking the wheel by the boss, boring out to a smooth $\frac{1}{2}$ in. and facing off the remaining shell of boss. The gears larger than 35 t. have inserted bosses, pressed into the wheel and additionally secured with a $\frac{1}{16}$ in. round pin—also pressed in. Here, you just press out the boss in the vice. This should leave the bare wheel with a $\frac{1}{2}$ in. hole ready bored. The keying pin will generally come out with the boss, but if not, it is easily pushed out of the bore in the wheel. If the $\frac{1}{2}$ in. hole left is smooth enough for use, that is all that is involved. There will be a small semi-circular notch in the hole at one point where the pin was, but this can be ignored. Should the hole be too rough for use or larger than $\frac{1}{2}$ in., then you will have to re-bush the wheel and bore it out to the required $\frac{1}{2}$ in. diameter. Should this be necessary, bore the wheel out to at least $\frac{7}{8}$ in. to provide for a reasonably thick walled bush.

All the gears are drilled close alongside the bore at two diametrically opposite points, one hole having a short pin pressed in. In use, when the wheels are paired up to run on the banjo studs, the pin in each engages the free hole in the opposite gear, so that each pair is keyed together with two pins. From this, it will be obvious that the holes need to be precisely located so that any one gear will readily lock with any other. The easiest way of ensuring this is to turn up a little drilling jig for the holes. This is merely a short length of 1 in. diameter rod, turned a close fit for the wheels up to a true shoulder. Turn the plug part fitting the wheels a shade short of $\frac{3}{16}$ in. —the thickness of the wheels—then when using it to drill the holes, the shoulder can contact the wheel really flat and closely. After the plug part is turned, leave it in the chuck and mark a pair of lines across the face of the shoulder exactly at centre height. This needs to be accurately done, and if you turn up the jig in the four-jaw chuck, a similar procedure can be adopted as was used to mark out the drilling points for the back gear pins in the ring, Mark in, too, a couple of arcs cutting the short lines, so that the cross-over points come on a circle of $\frac{11}{16}$ in. diameter.

The pins are short lengths of $\frac{3}{32}$ in. round rod, and if your rod is as exact to size as mine was, you will find that it will not quite enter a No. 42 hole. So drill both points on the jig No. 42 and de-burr the holes. Clamp the jig to one wheel and spot deeply through the jig into the wheel. As the jig need not be hardened just for these few holes, you can save wear and tear on it by not drilling right through every hole via the jig. Remove the jig and complete the drilling through both holes in the wheel. You should find that the $\frac{3}{32}$ in. rod, when chucked and faced on the end with a tiny chamfer, needs only two or three strokes with a fine file for it to begin to push tightly into the hole. Cut a piece to length—a bare $\frac{1}{8}$ in.—face the other end, and press the filed down end into the wheel in the vice. It need not be a really heavy press fit—just tight enough for it to resist being pulled out by the fingers.

Equip all the wheels with pins similarly, except for one 20 t. wheel left unpinned for the moment.

As the untreated outer end of the pins will not enter the hole already in the wheel, run through the lot and open up the free hole in each wheel with No. 41, or No. 40 drill at a pinch if any are reluctant to pair up.

There remains the driving collar on the clutch shaft to be drilled and pinned, and this can be treated exactly as if it was a gear wheel. The holes can be drilled right through this as a safety measure in case a pin needs to be driven out again for any reason, but the part of the pin pressed into the hole need not be any longer than that in any wheel. Take care to miss the grub screw with the pin holes.

The outer thick nut on the end of the mandrel also needs a pin, as this will drive the first wheel of any screwcutting train set up. You cannot use the drilling jig as it stands for this, as the nut is threaded ½ in. B.S.F., and so the jig will not enter it. It could be a good idea to keep the jig for possible use with some odd wheel acquired later, in which case it would be a pity to modify it so that it could not be used again for gears. The procedure therefore is to use the remaining unpinned 20 t. gear as the drilling jig. Unscrew the nut to about ¼ in. short of the mandrel end, slip the gear on the mandrel up to the nut and clamp it with a couple of small toolmakers' clamps to the nut. Unscrew the nut off the mandrel end, which will bring the wheel with it accurately centred about the threaded hole in the nut. Spot through the wheel into the face of the nut, locating the two holes at 90 degrees to the flats on the nut, separate, and drill the nut as if it was a gear wheel. Pin up both as before. A check round with all the various collars, nuts and wheels should show everything capable of being set up for any usable combination of wheels, with the mandrel turning the clutch shaft via the gears when turned by hand.

There are one or two little points that arise in connection with screwcutting with the baby lathe, in setting up change wheel trains for the various pitches of threads. Tables showing the wheels necessary and where they go are available in many books, but one is set out here which has been worked out especially for this lathe. This is necessary because although the 8 t.p.i. lead screw is quite conventional and common, the change wheels are not. The normal set of wheels starts at 20 t. and includes all those increasing in size by 5 t. up to 75 or so. This set ends off at the 50 t. wheel, this being the biggest; there is not room to accommodate larger wheels than this on the banjo. This means that where a train would normally be set up using, say, a 60 t. wheel, this has to be got round by the use of smaller wheels arranged differently. In a few cases this does away with the ability to cut a given pitch at all, but these are few and far between and all the usual pitches likely to be needed can be dealt with.

In a good many trains which can be set up, an idler wheel is required on one of the banjo studs. This means that only one wheel is occupying the stud, which is big enough to take a pair, and that the single wheel has to line up and mesh with one of a pair on another stud. The usual thing in such a case is to use a smaller wheel as packing—one small enough not to gear with any other "proper" wheel in the train. Sometimes, however, all the wheels small enough to be used for this duty will have been used elsewhere in the train. In that case, the answer is a collar, a simple plain affair of the same thickness as a gear wheel, and drilled in just the same way, although it need not carry a pin. This can then be pegged to any gear wheel and the pair—wheel and collar—turned either way on the stud to enable the wheel to take part in the train.

Sometimes a straightforward train works out so that the last driven wheel —that on the clutch shaft—needs to come in the outer position, and here again the answer is a plain collar on the shaft end in the position next the banjo, with the driving collar on the outside in the normal position. In this case, fit the gear wheel pin outwards, so that its pin engages the driving collar rather than the plain "spacer" collar; this gives you the benefit of two pins driving the gear wheel.

SCREWCUTTING CHANGEWHEEL CHART

		1st Stud		*2nd Stud*		*Lead*
T.P.I.	*Mandrel*	*Driven*	*Driver*	*Driven*	*Driver*	*Screw*
4	50	35	—	30	—	25
5	40	20	—	30	—	25
6	40	35	—	25	—	30
7	40	30	—	25	—	35
8	20	30	—	35	—	20
9	40	25	—	30	—	45
10	40	25	—	30	—	50
12	20	25	—	35	—	30
14	20	25	—	30	—	35
15	40	25	—	30	20	50
16	20	25	—	35	—	40
18	20	25	—	30	—	45
20	20	25	—	30	—	50
21	20	25	—	35	20	30
24	20	25	—	30	20	40
25	20	30	—	25	20	50
27	20	25	—	30	20	45
28	20	30	—	35	20	40
30	20	25	—	30	20	50
32	20	20	—	40	25	50
36	20	25	—	40	20	45
40	20	25	—	40	20	50
48	20	30	20	40	25	50
56	20	35	20	40	25	50
60	20	45	30	40	20	50
72	20	40	25	45	20	50

One last little worth-while item that has not been mentioned so far is a lead screw guard—a short "roof" over the lead screw on the headstock side of the saddle. This serves to keep small bits of swarf falling from the tool from sticking to the lead screw and getting carried along and worked into the saddle nut. It is merely a small rectangle of 20 S.W.G. sheet steel bent to shape and screwed behind the L.H. edge of the apron plate. Now that the clutch gear is all fixed up, the guard can be sized and fitted to clear everything that it should miss. It is held in place by two 6 B.A. countersunk screws through the apron plate. Drill and countersink these first, then holding the guard in place, spot through on to the guard for clearance holes in that. Attach it with a couple of screws nutted inside the guard and cut down short enough to well clear the lead screw.

And that concludes the actual construction of the lathe itself. One operation postponed from much earlier is the boring of the mandrel and tailstock for centres. This could still be delayed until after it has been decided what accessories are desirable; a faceplate, for one, can very conveniently be finished off by turning on the mandrel itself, and it may be found easier to do this with the mandrel mounted truly between centres in the lathe used in the construction so far.

CHAPTER SEVEN

Accessories

LATHES and cameras have one thing in common, and that is that the mass of accessories that it is possible to collect for either can occupy a much greater space than the basic article itself.

In the case of lathes, there is not quite the hard and fast line between what is a necessary fitment and what is an "extra" that is found with some other things. Given a chuck—or possibly two—with the lathe (which are generally treated as extras) it is possible to do a lot of work over quite a long period before the need is felt for a faceplate. Yet a faceplate is always included with the basic lathe as part of its equipment. If, as is likely, finding a chuck suitable for the lathe means looking around a bit, then the faceplate becomes more important than some other accessory for which the need might not arise until some time in the future.

Accessories as a whole are quite often made by the lathe user himself, either when the need for some special fitment arises, or as something useful and interesting to make soon after acquiring the lathe. The need for such an extra fitment generally dictates what form it must take, and it can of course be tailored to work in best with the lathe on which it is to be used. The productions of such items can safely be left to the individual needs and fancies of the lathe owner. However, something as basic as a faceplate could well be looked on as an item rather more essential than a genuine "extra", so some description of the making of the one shown might be welcome.

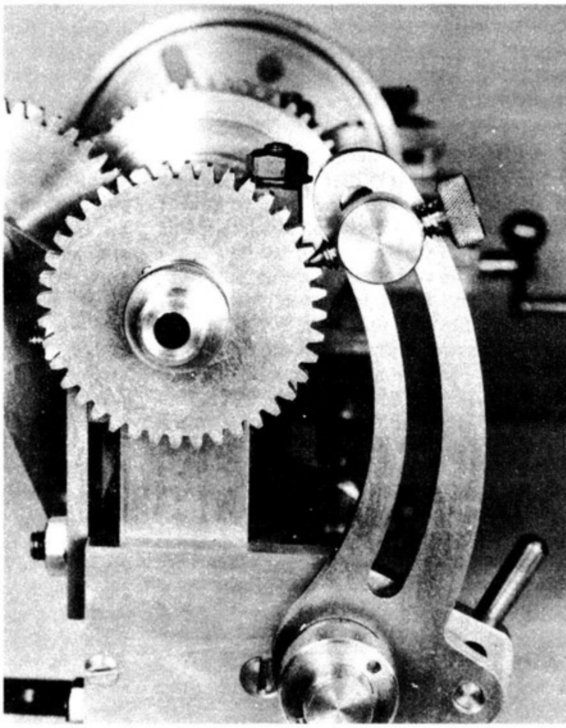
Faceplates are almost invariably machined up from a casting, and this course could very well be followed in making a small faceplate for this lathe. The pattern would be simplicity itself, being merely a flat disc provided with a central boss one side. The one shown was built up from plate and rod, the boss being inserted in a disc machined from the piece of plate.

The main disc is 3½ in. diameter, and is machined up from a piece of ¼ in. thick plate 4 in. wide. The plate can be an offcut of irregular shape of course, the shape for a start being quite immaterial so long as it is big enough for a 3½ in. disc to be marked out on it, leaving a little machining allowance round the edges. Mark out the 3½ in. circle clearly and centre punch the centre fairly deeply. Roughly saw the larger corners off the piece round the circle till it is no worse than irregularly octagonal. Drill the centre point ⅜ or ½ in. diameter for mounting the piece on a stout bolt for turning.

Mount the piece on the bolt, chuck the bolt in the three-jaw chuck and start the turning with the outside edge. The first cuts until the tool is cutting nearly all the way round will need to be quite light, or the tool will catch up on one of the points causing the bolt to slip in the chuck jaws. When the tool is cutting all round giving a smooth edge to the disc, leave a little on the edge still to come off and remove from the chuck. Remove the central bolt and if necessary fit the other set of jaws to the chuck to grip the disc by its outer edge. Check that the disc is nicely square in all directions in the chuck and bore the hole out to a smooth ¾ in. diameter. The outer face of the disc will be the back of the faceplate, so take a very light skim over the central 1½ in. diameter or so to provide a true surface for the boss to bed against. Scrape a tiny chamfer to the edge of the hole with a smooth swiss file to aid in fitting the boss. As this is as far as we can go with the plate at this stage, remove from the chuck and re-fit the normal jaws if these were changed over.

The boss is turned from a chunk of 1 in. diameter round steel rod. Chuck in the three-jaw and face one end. Reverse in the chuck and face the other end, centre drill, and drill right through ⅜ in. diameter. With a small boring tool bore

Fig. 25. Detent mounted on banjo for indexing round 40 t. change wheel.



out to $\frac{1}{2}$ in. B.S.F. tapping size—$^{27}/_{64}$ in. full. Screwcut the thread in the boss $\frac{1}{2}$ in. B.S.F., 16 t.p.i. Run the $\frac{1}{2}$ in. tap through to size and shape up the thread, holding the tap in the tailstock chuck and pulling the lathe round by hand. Leaving the piece in the chuck when the tap has run through, you can check the fit of the mandrel nose in the thread. This should screw smoothly in up to the larger diameter register of the mandrel. Incidentally, the length of the piece for the boss will depend on the length of the mandrel nose, i.e, the threaded portion plus the width of the $\frac{5}{8}$ in. diameter register. Make the boss anything from $\frac{1}{32}$ to $\frac{1}{16}$ in. longer than this dimension, so that the end of the mandrel is slightly below the face of the plate when it is fitted to the mandrel.

The next step is to bore out the start of the thread to $\frac{5}{8}$ in. diameter, so that the mandrel screws right in firmly up to the face of the flange, with the register a smooth shakeless fit in the bore of the boss. The mandrel when so screwed in should run quite truly when held by its nose in the boss. When you reach this state of affairs the boss can come out of the chuck.

It is assumed that the mandrel is still undrilled through, with the centres still in good shape each end. A nice true fitting should result from using these to finish turn the faceplate on its own mandrel. So mount the mandrel between centres, nose towards the tailstock, with the faceplate boss screwed in position. The outer end of the boss now has to be reduced to fit in the plate, and this needs to be a firm press fit—or firm push fit with Loctite. Take the reduced end back till the width is a fraction less than the thickness of the plate, which will allow for a light cut across the face of the plate to true it up. When the fit looks about right, unscrew the boss from the mandrel and assemble it to the plate, making sure

that it goes into what was to be the back of the plate.

When the two pieces are firmly assembled together as one, remount the plate on the mandrel and the mandrel between centres, and skim the edge of the plate down to the scribed circumference line. Take a very light cut or two with a newly stoned-up sharp tool and slow cut right across the face of the plate. The plate could very well be reduced in thickness down to $\frac{3}{16}$ in. or so, turning a bare $\frac{1}{16}$ in. off the back and leaving a narrow rim some $\frac{1}{8}$ in. wide the full thickness of the piece all round the edge. This could be done either with a L.H. tool with the plate mounted on the mandrel between centres, with the plate held by the outer edge in the chuck, or by mounting the plate on the mandrel "back to front" with a temporary spacer between the face of the plate and the mandrel flange. Whichever way it is done, a light finishing cut could be taken over the outside of the boss and a finishing chamfer turned on the outer edge at the same time.

Here is another place where you can do some simple dividing for the faceplate slots, either holding the plate in the four-jaw chuck or mounting it on the mandrel held in the four-jaw. Using the four-jaw is not for the purpose of aiming for super accuracy—the slot positions are not all that critical—but for the facility of using the four-jaw positions for indexing round. Marking the slot centre lines can be done either on the front or the back of the plate; doing it on the back leaves the front completely unmarked, should this be looked on as a desirable feature. Bolts $\frac{1}{4}$ in. diameter for holding jobs on the plate are amply big enough for a plate of this size, so the slots can be produced from $\frac{1}{4}$ in. holes along the lines of the slots, filed out to smooth-sided slots. Individual additional $\frac{1}{4}$ in. holes can be strategically located between the slots to fancy, or drilling these could be left till the urgent need for some arises. However, like additional holes in the cross slide, it would be as well to avoid an unbalanced collection of random holes resulting from taking the easy way out with a variety of jobs.

If the purchase of a small chuck is intended shortly, it might pay to preserve the centres in the mandrel till after the chuck is obtained, as an exactly similar procedure is involved in machining up the backplate for a chuck as was needed for the faceplate—except that a chuck backplate would be a one-piece item. However, chucks of a size suitable for a small lathe like this generally have the body itself threaded for the mandrel nose, so that no backplate is required. This is done to avoid the slight extra overhang involved in fitting a separate backplate. In this case the threading of the body would best be carried out in the bigger "construction" lathe, gripping the small chuck bodily in that of the bigger lathe. So assuming that either no chuck backplate is required, or that if it is it has been made, the mandrel and tailstock could be taken in hand for boring and fitting of centres.

The size of the centres is specified as No. 0 Morse. Tables of standard taper sizes give this as a taper of .625 in. per foot, starting from a small end diameter of .252 in. and increasing to .356 in. in a length of 2 in. The taper of $\frac{5}{8}$ in. per foot results in an included angle of 2 deg. 59 min. 4 sec.; this could safely be called 3 deg. for our purposes. Checking with a commercially made No. 0 centre, this is rather too long for a comfortable fit in the size socket that could be bored in our pieces, and it is not advisable to try and remove a lot of metal from a hole with a taper reamer or D-bit. The result of so doing is generally severe scoring in the hole. So the best procedure is to bore out the taper hole with a slender boring tool and restrict the diameter of the centre at the larger end to about $\frac{5}{16}$ in. This results in a handy size centre, having a length over the taper portion of some $1\frac{1}{8}$ in. This should be stout enough and seat securely enough in the socket to be able to cope with the size of job likely to be tackled on a lathe of this size.

Start operations on the tailstock barrel. If this is not bored right through as yet, chuck it screwed end outwards and get it running true. Start to drill in the centre hole $\frac{7}{32}$ in. diameter and go about half-way in. Reverse in the chuck and make

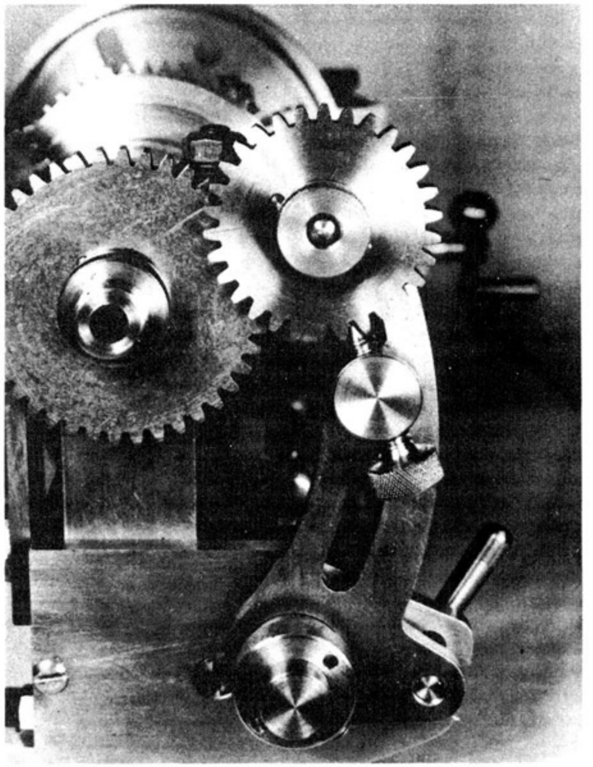


Fig. 26. Using the detent for compound dividing; indexing round the 30 t. wheel for 12 positions.

sure that the outer end runs true, drilling in to meet the $\frac{7}{32}$ in. hole in the other end. This end could be drilled $\frac{1}{4}$ in., but there is one point to note. If you intend to make the simple lever feed attachment for the tailstock—and this is well worth while—leave about $\frac{1}{2}$ in. or so of the $\frac{7}{32}$ in. bore at that size at the back outer end, as the hole needs to be tapped $\frac{1}{4}$ in. B.S.F. for attaching the lever feed gadget.

With a true $\frac{1}{4}$ in. hole well into the barrel, the taper mouth can be bored. If you have a commercial centre for use as a check gauge, setting the top slide over $1\frac{1}{2}$ degrees will be found almost exactly the right angle for a start. Don't forget that the tool height will affect the taper of the hole produced, so when you get the height just right so that the boring tool is cutting nicely as nearly as you can get it to exact centre height, leave the height alone and make any slight adjustments necessary by varying the top slide angle. In so gentle a taper, the slightest alteration to the top slide setting will make a big difference to the shape of the hole, so if you do have to alter this, do so by the smallest possible amount.

If you do not have a commercial centre to refer to—and one could be borrowed just for this job—leave the tool at centre height and and the top slide at $1\frac{1}{2}$ degrees and bore out till the tool ceases to cut at something like a full $1\frac{1}{8}$ in. in, and the end of a $\frac{5}{16}$ in. drill shank shows the outer end of the hole to be about that size. Boring both holes first, without disturbing the tool setting, will give you the best chance of getting both exactly alike and also enable you to produce two identical centres.

With the tailstock socket bored smoothly out to size, move on to do the same with the mandrel. This could be

drilled right through $\frac{1}{4}$ in., as there is nothing required to screw in either end necessitating a tapping size hole. Grip the mandrel in the chuck tail end outwards, with the screwed nose inside the chuck. My $\frac{1}{4}$ in. drill seemed to be about standard length when compared with others and was only just long enough to drill halfway through the mandrel, gripping it for the last little bit by the extreme end in the tailstock chuck. Deep drilling like this tends to be a slowish process, as the drill needs withdrawing at shorter intervals to clear the chips as the hole gets deeper. This is because the deeper the drill penetrates the more difficult it is for the swarf to find its way up the drill flutes—especially when the end of the flutes are enclosed in the starting end of the hole. Frequent withdrawals are useful, too, to keep the drill point well doped with cutting oil; this helps in keeping the drill point cool, as a fair amount of heat is developed and retained at the bottom of a deeply drilled hole.

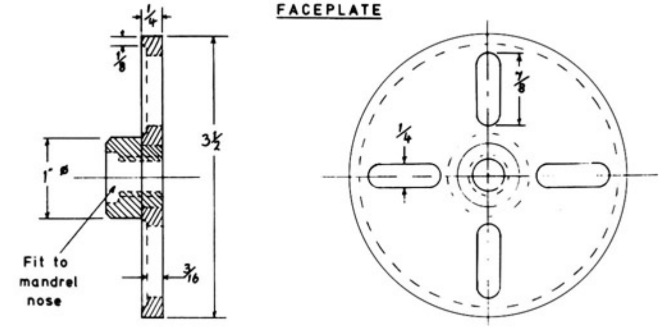
When the drill has gone in as far as it will reach, reverse the mandrel in the chuck and get it running quite truly. The through drilling may as well be completed from this end before starting the boring, as the clear way through will help clear the chips resulting from boring the socket. The boring is just as for the tailstock, taking it out to a smooth finish to the same size. When the socket is finish bored, leave the mandrel in the chuck as the socket will be running dead true, and take the chuck off the lathe without disturbing the mandrel as set up. By using the other chuck for turning the actual centres, the true-running mandrel socket can be used for turning the points of the centres, which should ensure the truest possible result.

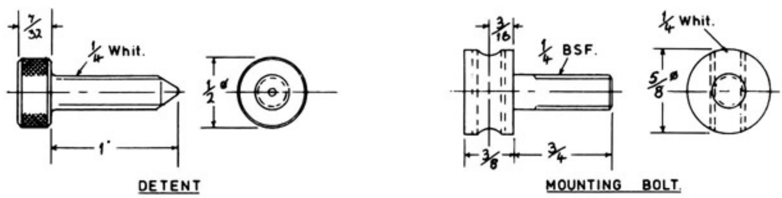
The tailstock centre needs to be hardened, which means turning it out of silver steel. There is no reason why they should not be both of the same material, although ordinary mild steel is quite acceptable for the headstock centre. It is customary to skim this one up from time to time to ensure that it has a really truly running point before starting on some important job, and this, and the fact that it is not subject to wear through the job revolving on it means that it needs to be left soft. A short length of $\frac{5}{16}$ in. rod is suitable for turning the centres, and this should be chucked to run truly with about $1\frac{1}{4}$ in. projecting from the chuck. Slack off the top slide fixing and swing this to the $1\frac{1}{2}$ degree angle the other way, so that the smaller diameter will be at the outer end. Use a roundnose tool with not too small a radius on the point so as to get a good finish. Run the lathe at not faster than middle direct speed and take very light cuts, feeding with the top slide only. As soon as you have some $\frac{1}{2}$-$\frac{3}{4}$ in. of turned taper on the piece, try it for fit in the bored tailstock barrel. The top slide setting should be corrected if necessary for a good fit on the taper well before the piece is down to size, as there is very little to come off to bring the centre down to final size. Turn it down till you have a snugly fitting taper in the socket about $1\frac{1}{8}$ in. long and of a good finish. When you have, remove it from the chuck and cut it off to leave some $\frac{1}{2}$ in. of parallel rod beyond the end of the taper. Then it is all over again for the second one. If this second one is to be for the mandrel, the fit of the taper could be finally checked in the mandrel socket, although it is not too easy to feel the fit when it means handling the heavy chuck as well to offer up the mandrel. The tiniest little adjustment to the fit can probably be corrected by some very light filing with a dead smooth file with the piece running in the lathe, although this is a procedure that tends to be frowned on by expert turners!

When you have the second centre finished down to size, cut it off like the first one and remove the chuck. Replace the first chuck on the lathe complete with mandrel undisturbed, and then you can plug in both centres for turning the points. Set the top slide over to an indicated 30 degrees, which will produce the conventional 60 degrees centre point, and face off the cut end. Again using the top slide only for feed, turn the point to a smoothly finished cone with a sharp point. Similar treatment for both centres, of course.

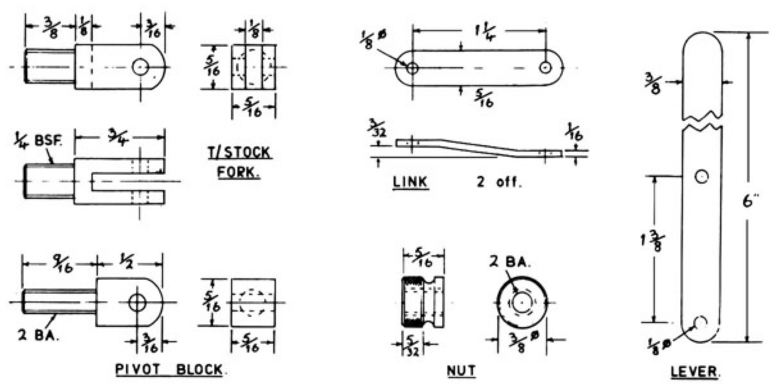
The tailstock centre is hardened in the normal way, heating it to a bright cherry

FACEPLATE





CHANGE WHEEL DIVIDING ATTACHMENT.



TAILSTOCK LEVER FEED

red and quenching out in water. In heating it up, keep the flame away from the extreme point, else this may get burnt from overheating and crumble. Polish up the hardened centre on the taper-turned surfaces.

* * *

An operation that can be carried out very well in the lathe is indexing or dividing. This involves the accurate positioning of a ring of points or holes on a circle of a given diameter. This could be necessary for something like bolt holes for the end cover of a model steam engine cylinder, for instance. In this case the number concerned would probably not be very large; some simple dividing for three and four holes has already been necessary in building the lathe itself.

The lathe, however, can carry out indexing in respect of much bigger numbers than we have been concerned with so far, and this works in very happily with the fact that the piece of work on which the indexed points are required is quite often something which has been produced by turning—or if not, then the surface on which the dividing is required probably has been. The piece can therefore be left in the lathe as from turning and the indexing carried out straightaway, resulting in the indexed points being accurately located in relation to the dimensions of the surface just machined. Examples of this could be the holes for rivets round the turned flange of a small boiler end, or for spoke locations round the rim of a small wheel. Another type of wheel which might very well be produced on a lathe of this size is a clock wheel, and positioning the teeth round the edge of such a wheel obviously involves much larger numbers than could be produced by using makeshift stops for the chuck jaws.

The lathe's own change wheels represent a ready made set of dividing plates, and it is simplicity itself to make use of any of these for that purpose. The attachment which enables this to be done hardly warrants the name of attachment, and the whole thing can be made in a couple of hours or so. This short time in making it would be well spent, as it can be used to produce all the smaller numbers as well as those not easily obtainable by any other means.

Any one of the change wheels can be positively fixed on the end of the mandrel by means of the driving pins and holes in wheel and mandrel collar. To go with this is needed some sort of firmly located detent to engage the space between any two teeth of a change wheel, so that it can be quickly withdrawn to move the wheel and then re-engage with a different tooth space in exactly the same position. It will be appreciated that any selected change wheel will provide several accurately spaced rings of points, the number of such positions depending not only on the size of the wheel in use, but also on the number of teeth between each space selected by the detent. Thus the 40 t. wheel, for instance, will provide 2, 4, 5, 8, 10, 20 and 40 divisions, and other wheels with differing numbers of teeth can obviously provide further ranges of numbers. Exploring fully the possibilities of every change wheel in the set produces a great many possible numbers, sufficient to meet most normal requirements.

In indexing round a single wheel for a small number which is obtainable from any of several wheels, it is preferable to use the biggest wheel that can be accommodated for the sake of accuracy of the located points. Thus if, say, 5 positions are required, indexing round every 10th tooth on the 50 t. wheel could provide a slightly more accurate result than picking up every 4th round the 20 t. wheel.

However, the possibilities do not end there. In the same way that the change wheels can be set up in various ways and combinations to produce a wide range of thread pitches, so they can also be set up to enable a number to be indexed which is not obtainable direct from any single wheel. For instance, suppose it is required to index for 18 positions. There is no wheel of 18 t. in the change-wheel set, nor one of any multiple of 18. So what is done in this case is to work from a wheel which will provide a number which will lead up to 18. If the 45 t. wheel were mounted on the mandrel and tooth spaces 5 t. apart indexed round, we should come up with 9 positions, as 9 x 5 t. = 45. If we now arrange a 2:1 ratio pair of wheels to

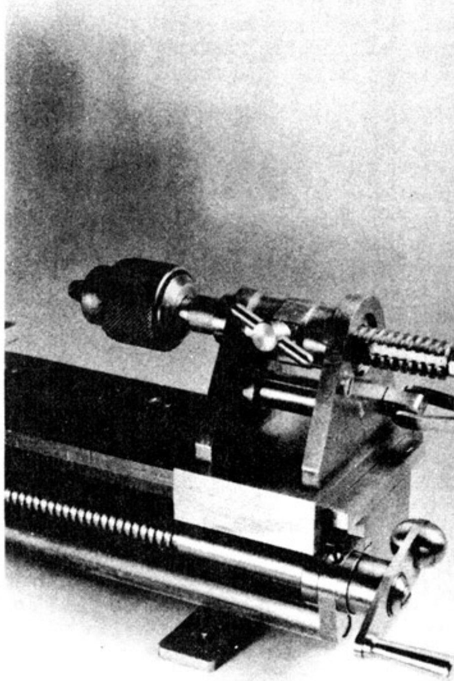


Fig. 27. Tailstock lever feed attachment fitted, as for fine drilling.

multiply that 9 positions by 2, the result is the required 18 points. The curtailed set of change wheels for this lathe can provide only two 2:1 pairs: 20-40 and 25-50. Suppose we use the smallest pair; in that case the 40 t. goes on the mandrel, and the 20 t. on the first banjo stud to gear with it. Pinned to the 20 t. on the same stud goes the 45 t. wheel, and the procedure is to index round the 45 t. wheel every 5 t. as for the basic 9 positions. When the 9 points have been indexed round the 45 t. wheel, as it is geared down 2:1 to the mandrel, the mandrel will only have made half a turn for the whole revolution of the 45 t. wheel, so indexing round another 9 positions of the 45 t. wheel is needed to complete the second half turn of the mandrel to produce 18 points altogether.

It should be evident that what is actually being done in this sort of procedure is to find a wheel whose number of teeth has a common factor with the number required. In many cases there is more than one way of arriving at the required number. For instance, the 18 position example detailed above, given a wide enough range of wheel sizes, could be obtained by 6 positions from the 30 t. wheel multiplied by 3 from a 3:1 ratio pair. As the smallest wheel is the 20 t., the smallest 3:1 pair would be 20-60, which cannot be done on this lathe, lacking the 60 t.

The detent for carrying out any of the dividing operations possible consists merely of a coarse pitch pointed screw, having a knurled head for finger operation. The coarse pitch is useful in running it back and forth into and out of engagement with the indexing wheel. The screw runs through a hole tapped across what is in effect the head of a special bolt, this being clamped in the banjo slot like a change-wheel stud. In indexing round a

single wheel on the mandrel, the gadget can be mounted near the top of the banjo slot so that it comes about level with the mandrel, then the screw need not be screwed in and out to locate each new position. Instead, the banjo can be unclamped and swung back slightly—just enough to swing the detent point clear of the wheel. Having counted round to the next position, the banjo is swung forwards again to engage the detent and locked in position to hold the mandrel.

If the indexing is being carried out with the extra "gearing down" pair of wheels, this cannot be done, as any movement of the banjo will carry the extra pair of gears with it, disengaging the smaller wheel from the mandrel wheel and losing the position. So in indexing this way—known incidentally as "compound indexing"—the movement of the detent must be by screwing it in and out.

A point crops up in connection with compound indexing, and that is the actual position of the detent. If the large wheel of the reduction pair is on the mandrel in the usual position and the smaller one of this pair on the banjo stud in position to engage it, then the indexing wheel must be on that same stud in the outside position. This means that the detent must be one wheel thickness further out from the banjo than it is when indexing direct on to a wheel on the mandrel.

This difference is easily taken care of by the use of a $\frac{3}{16}$ in. thick washer under the head of the mounting bolt. If the length of thread on the stem of the bolt is such that the bolt can be clamped in position on the banjo with the packing washer either side of the banjo, then the washer can conveniently always be used on the bolt in whichever place it is called for.

Making the accessory is so simple as to call for no detailed description, but there are a couple of points to watch with the detent. Shape the point so that the tip does not contact the bottom of the tooth space, the contacts being only on the two flanks of the teeth, and make the screw a shakeless fit in the mounting bolt. Any slight play could allow the wheel being indexed to move slightly when the detent is engaged, losing the accuracy of the positioning of the indexed points. In use, take up any slight backlash or play between wheels always the same way when engaging the detent. Adjusting the mandrel to turn a trifle stiffer can help there.

* * *

The lathe accessories that are likely to prove of the most use are those that enable the lathe to do a better job on the sort of work for which it is mostly used.

One gadget to which this definitely applies is a lever feed tailstock attachment. The size of lathe described here is likely to be used a great deal for small components falling into the "fiddly" class, and there are many such calling for small holes to be drilled—bushes for small shafts, carburetter jets and the like. Drilling small holes of any depth calls for a somewhat different way of handling the drill as compared with much larger holes made by a sturdy, stiff drill. Really small holes need a very light pressure on the drill, with extremely short periods of actual drilling between withdrawals of the drill to clear the resulting minute chips. In fact, if the drill can be given a "pumping" action, with a brief pause for drilling between withdrawals, this is the ideal procedure. This is not too easy with the normal equipment of a screw-feed tailstock barrel, but is infinitely easier and quicker with the lever attachment shown.

It is made almost entirely from narrow strips, and consists of a short hand lever pivoted at the bottom end between a pair of short links, which in turn swing about a small block attached to the base of the tailstock. Another small slotted block further up the lever screws into the end of the tailstock barrel, so that swinging the top end of the lever slides the barrel to and fro in the tailstock housing. The bottom anchor block is attached by a single finger nut towards the rear of the tailstock, bringing the top operating end of the lever conveniently forwards. To bring the attachment into use, the two screws holding the feed-wheel keep plate are removed, the keep plate and wheel also removed, and the top block on the lever screwed into the outer end of the

tailstock barrel. Inserting the bottom pivot block into its hole in the back plate of the tailstock and nutting up sees the attachment fitted and ready for use.

There is nothing at all critical about the sizes of the various pieces of the attachment, and the two pivot blocks can be quickly shaped up from $\frac{5}{16}$ or $\frac{3}{8}$ in. square bar. In fact, I made the two on the attachment shown from $\frac{3}{8}$ in. hexagonal rod. The bottom one holding the links is a plain turning and threading job, having a $\frac{1}{8}$ in. diameter hole drilled across it for the link pin. The threaded mounting stalk is 2 B.A. The upper block is much the same, except that the stalk is threaded $\frac{1}{4}$ in. B.S.F. to screw in the tailstock barrel. Face the end of the bar in the lathe first, and then cut the slot for the hand lever; having a length of material available for holding makes it easier to shape the slot than if the piece is cut to final length first. The slot can be machined right out in the one go with a saw-type cutter mounted on a stout bolt for an arbor—taking several cuts if it is a thin cutter. Alternatively, a perfectly satisfactory slot results from sawing down to a previously drilled hole and smoothing up the slot to size by filing.

The lever is merely a 6 in. length of $\frac{3}{8}$ x $\frac{1}{8}$ in. steel strip, drilled for the two pivot pins and having the ends rounded. The swing links on the bottom block are short pieces of $\frac{5}{16}$ x $\frac{1}{16}$ in. strip. Mark out one for the positions of the two holes, then clamp the two together for drilling the holes and shaping the ends. Bend the ends to give them a slight "joggle" so that they lay flat against the sides of the pivot block and the bottom of the lever.

The pins on which the links and lever pivot can be $\frac{1}{8}$ in. snap or round head steel or iron rivets, or like the example shown, merely short lengths of $\frac{1}{8}$ in. round steel rod cut to length and lightly riveted in place. Take care when riveting not to clench them down too tight, so gripping the links or lever and making things stiff to operate; one of the good features about the thing as a whole is that it does provide a sensitive feel to the action of the drill. To preserve that feel, the tailstock lock screw should be slacked off enough to allow of perfectly free movement by the tailstock barrel, at the same time keeping it in engagement with the keyway so that the barrel cannot turn from the torque of the drill.

A suitable spot for drilling the hole for fixing the attachment is near the bottom rear corner of the tailstock back plate, say $\frac{3}{8}$ in. up from the base and the same amount in from the bottom corner. A neat knurled 2 B.A. finger nut can be turned up from a stub of $\frac{5}{8}$ in. rod, or a standard nut can be used. Providing the finger nut cuts out the need for a spanner in fixing.

So . . . with the lathe and this small handful of accessories complete, the builder should be in a good position to produce for himself anything further that may be required, be it further accessories or "genuine jobs"!

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